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LOCOMOTIVE SUPERHEATERS AND THEIR PERFORMANCE.*

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PART I.

AN interest in the subject of superheaters, which has continued for over two centuries, and has culminated at the present day in their almost universal application to steam locomotives, can be shown to have been fully justified by the substantial economies now derived from the use of superheated steam.

It will be my purpose to trace first the history and development of locomotive superheaters, and then to show, from tests, some of the effects of superheating, and the advantages of its use in a large passenger locomotive.

Superheating, or what in the early days was termed "overheating" of steam, has been used and studied since the earliest inception of the use of the expansive force of steam, because we find that Dionigi Papin, as early as 1705, superheated steam by means of a red-hot bar placed in the cylinder itself, and he describes the process as "the steam receiving greater expansion than in the boiler."

Henry Wood in 1759, Joseph Hatley in 1768, Thomas Mead

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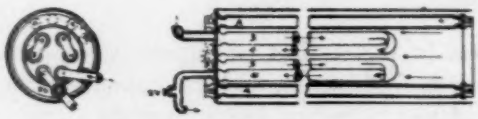
in 1791 and Arthur Woolf in 1804 made studies of devices involving the use of superheated steam. It was not, however, until 1832 that the inventor and constructor of the first steam locomotive, Richard Trevithick, made a practical application to a locomotive. His superheater is shown in Fig. 1. In his patent, No. 6308, 1832, he describes his method of superheating as:

"The interposition between the boiler and the cylinder of a long pipe heated and curved in the form of a buckle through which the steam is obliged to pass with great rapidity and without ever entering into contact with the water."

This figure illustrates, as far as the author's knowledge goes, the first conception of a superheater of the general form now in use, and it is noteworthy that the design embodied some of the essential features of modern practice, as will be pointed out later when tracing out the development of the various forms of superheaters.

FIG. 1.



TREVITHICK'S SUPERHEATER, 1832, FIRE TUBE TYPE.

The first design of a locomotive superheater. The superheating element, consisting of a return tube inserted in the fire tube of the boiler, is essentially the same as that used to-day.

While the invention and development of superheaters as applied to locomotives have been principally along four general lines, it is of considerable interest to observe, as well, that but one type has come into popular favor and wide use, and this is the fire tube type.

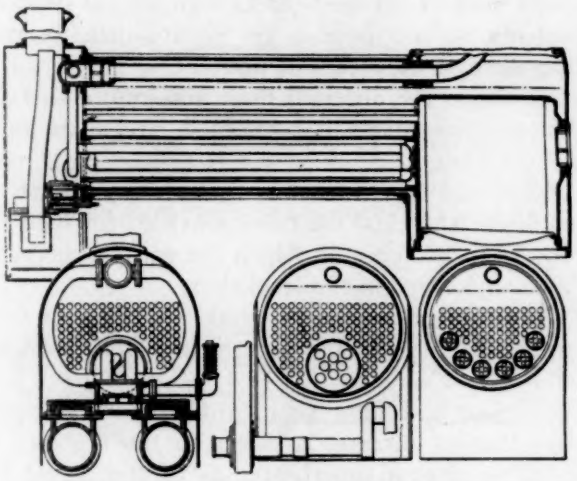
In the arrangement for this method of superheating, as in the case of Trevithick's invention, 1832, the steam, after leaving that portion of the boiler in which it is generated, is passed through either straight or bent pipes, located in one or more enlarged fire tubes of the boiler, the pipes for conveying and superheating the steam extending to a point as close to the furnace fire as is permissible by the tube arrangement of the boiler.

A second form which received some attention in the early application to locomotives is known as the smokebox type, and in this an attempt was made to utilize, for superheating, some

of the waste heat of the gases of combustion after they had passed out of the boiler tubes proper. This design has attracted special attention, for the reason that the superheating was accomplished by a utilization of what otherwise would be wasted heat and because it furnished a superheat of low temperature, and thus avoided trouble with cylinder packing and lubrication.

A third arrangement, where the superheater occupies a portion of the barrel of the boiler and uses part of the length of the fire tubes for superheating, has never had extensive application, although it has appeared from time to time in the construction of locomotives, both in this country and abroad. Its advocates

FIG. 2.



DE MONTCHEUIL'S SUPERHEATER, 1850, FIRE TUBE TYPE.
Three possible arrangements of the elements in the fire tube are shown

were apparently seeking an intermediate temperature of superheat, higher than that which could be provided by the waste heat superheater, but at the same time they did not care to utilize the high temperature of steam produced by the fire tube type, the first mentioned.

A fourth method, viz., furnace or firebox type, in which the tubes containing the steam to be superheated are placed immediately in contact with the fire, has been devised within the last thirty years. By such an arrangement it is possible to obtain the highest degree of superheat with the least area of heating surface. This construction has met with very little success,

probably due to the fact that means have not been provided to take care of the high temperature to which the steam tubes are subjected. The possibilities of this and the other constructions will be touched upon in discussing the details of each of the types mentioned.

The fire tube superheater is the simplest form, and the earliest arrangement of it is shown in Fig. 1. The construction of Trevithick was made applicable to a locomotive by De Montcheuil in 1850 (see Fig. 2, which shows De Montcheuil application to a locomotive of the Montereau & Troyes Railway). His construction, somewhat modified, is used to-day in the application of superheaters to modern locomotives. Designs based on this arrangement furnish a superheat as high as 300 degrees with a boiler pressure of 200 pounds per square inch, corresponding to a temperature of the steam of 690° F.

The devices, in the order of their importance so far as their application to locomotives is concerned, are again outlined as follows:

1. The fire tube type, in which separate superheater elements are placed inside of special fire tubes provided for their reception.

2. The smokebox type, in which the entire superheater, or a portion of it, is located in the smokebox.

3. The boiler barrel type, in which a portion of the heating surface of the fire tubes of the boiler is used for superheating the steam.

4. The firebox and flue type, in which a portion, or the entire superheater heating surface, is placed in the firebox.

Whether to class a superheater as of the barrel or of the smokebox type is often a question, particularly when the water-heating surface is encroached upon to permit of a large area of superheating surface.

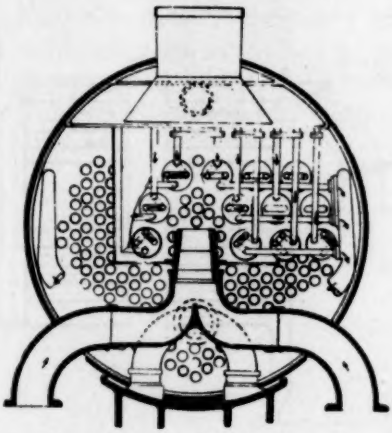
The various superheaters will now be discussed in greater detail with typical illustrations under each classification.

FIRE TUBE TYPE.

The superheater now in most general use is undoubtedly essentially the same as that applied by De Montcheuil to an express passenger locomotive on the Montereau & Troyes Railway in France about 1850. This construction is shown in Figs. 2, 3, and 4. Here we find separate elements, coupled to a header, and

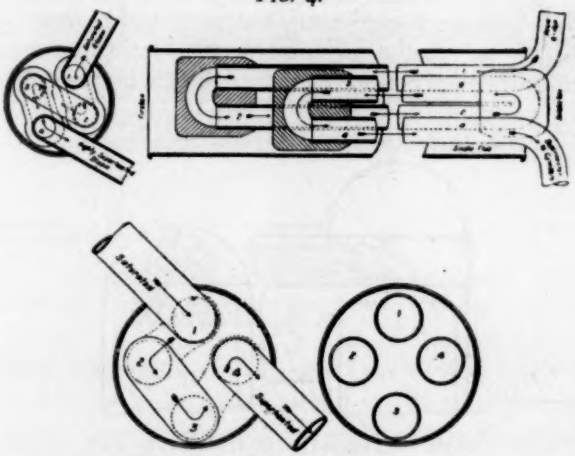
the elements located in a number of large fire tubes in the barrel of the boiler. The hot gases, in passing from the firebox to

FIG. 3.



DE MONTCHEUIL'S SUPERHEATER, 1850.
In all essential details this superheater is the same as the Schmidt fire tube type now used.

FIG. 4.

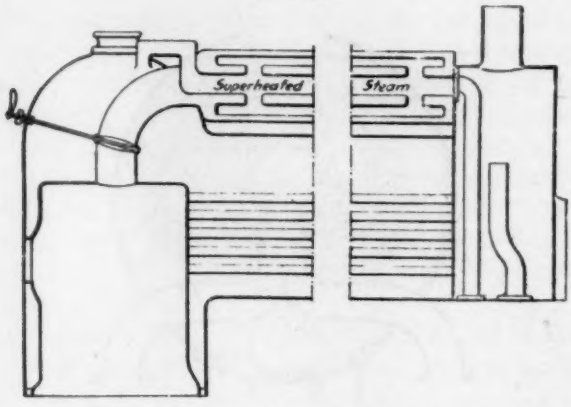


DE MONTCHEUIL'S SUPERHEATER, 1850.
Details of the superheater element in the fire tube.

the smokebox, surround these small superheater elements, through which saturated steam is allowed to flow from the

throttle of the locomotive to the steam chest, and in the passage through the heated elements this steam becomes superheated, due to its separation from the steam in the boiler.

FIG. 5.

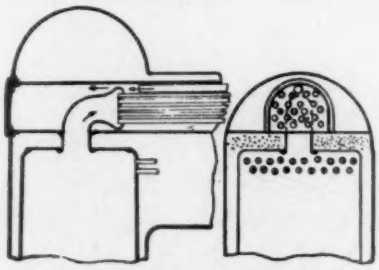


DE MONTCHEUIL'S SUPERHEATER, 1850, FIRE TUBE TYPE.

The gases are conveyed through a large tube connected to the crown sheet of the firebox. This early form of superheater shows the use of a damper in the gas passage.

Fundamentally, this design represents the most advanced practice of to-day in the production of superheated steam. Improvements in construction over that shown in these figures tend

FIG. 6.



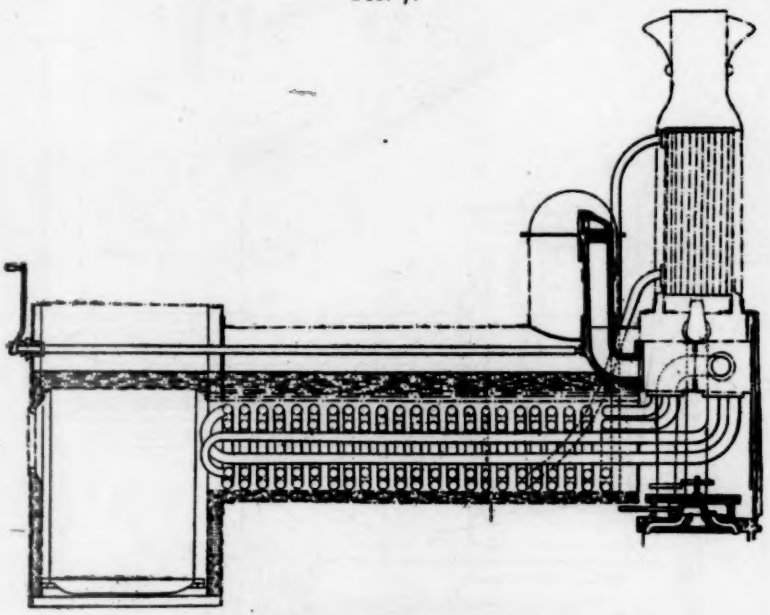
LLOYD'S SUPERHEATER, 1851, FIRE TUBE TYPE.

This superheater is very similar to that shown in Fig. 5.

largely to the perfection of details to minimize the cost of maintenance and the possibility of failure in service. It may therefore be said that De Montcheuil paved the way for future suc-

cessful designs, but his own experiments probably did not work out satisfactorily in practice, due to difficulties in the handling of the steam after superheating, from lubrication and packing troubles, and the general use of superheated steam for locomotives appeared to have been delayed for nearly fifty years, owing to these practical considerations which had to be worked out in the use of the high temperature steam. De Montcheuil devised at about the same time another form of superheater as shown in

FIG. 7.



MONTELY'S SUPERHEATER, 1855, FIRE TUBE TYPE.

The superheating element consists of a coil in a large fire tube. The early form of the Schmidt superheater is similar (see Fig. 11).

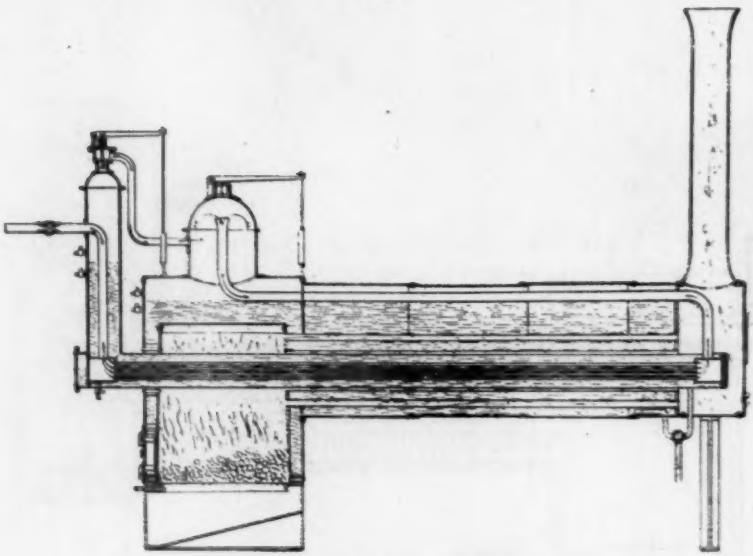
Fig. 5. It is interesting to observe that at this early date he proposed a damper to check or retard the flow of furnace gases over the superheater, to provide against its becoming overheated.

Following De Montcheuil we find, in the year 1851, that Richard Lloyd, residing in Paris, invented a modification of this superheater in which the tubes for superheating were in communication with the crown sheet of the boiler to utilize the heat of the gases after they had left the firebox, rather than after they

had left the front tube sheet. Fig. 6 gives an idea of the construction.

A superheater invented in 1855 by P. J. C. Montely, of Toulon, France, is shown in Fig. 7. The diagram illustrates an attempt of the inventor to provide a construction which would satisfactorily superheat the steam and at the same time utilize some of the heat of the waste gases for this purpose. The placing of the superheater element tubes in the barrel of the boiler in one large flue was an early use of a construction revived by

FIG. 8.

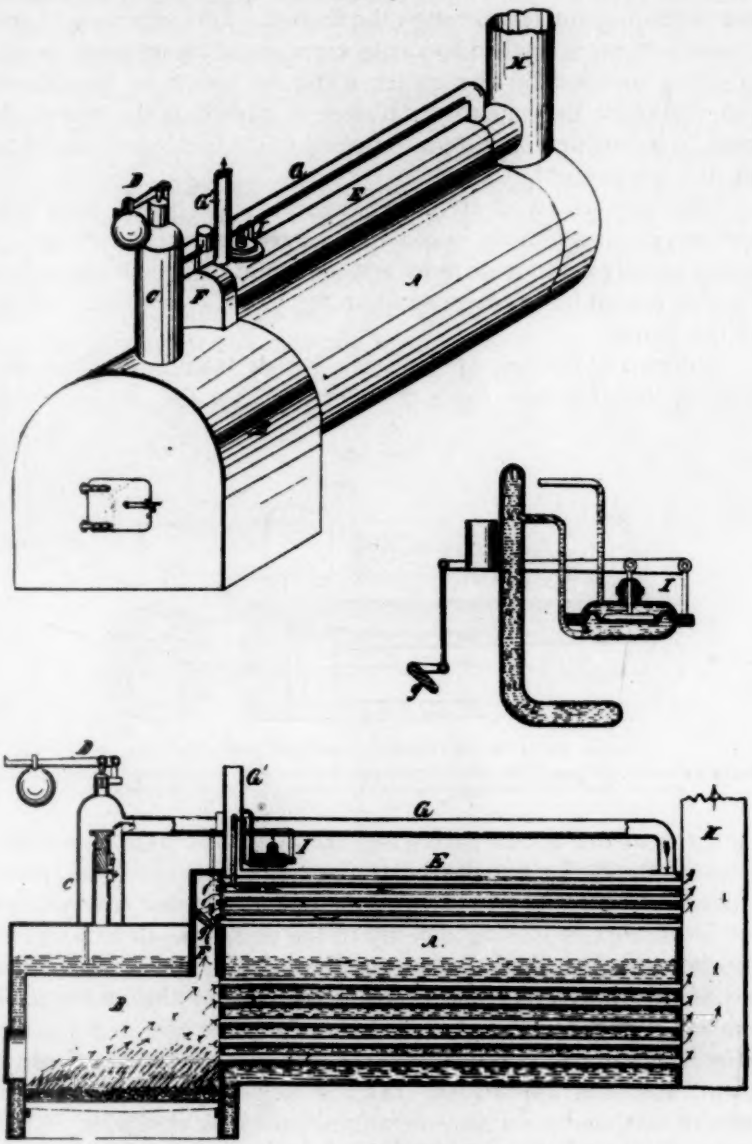


STORM'S SUPERHEATER, 1857, FIRE TUBE TYPE.
In this scheme for a superheater the elements are surrounded by water.

Schmidt in 1898, but later abandoned, owing to difficulties in keeping steam-tight the large flue in which the elements were placed.

The first United States patent for a fire tube superheater was issued to W. M. Storm, of New York City, in 1857. His object was to effect economy in the use of steam by placing the superheater in the boiler without exposing it to the direct action of the fire or hot products of combustion. By referring to Fig. 8 it is seen that his arrangement consists of a comparatively long

FIG. 9.



STILLMAN & WILCOX SUPERHEATER, 1859, FIRE TUBE TYPE.

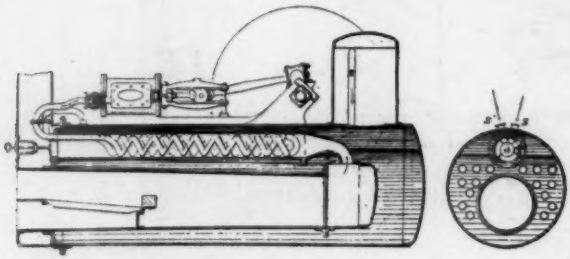
This superheater is outside of the boiler and part of the hot gases are deflected and passed through a large tube containing the superheater elements. Another early suggestion of a damper for the furnace gases is shown.

internal flue, one end terminating in the smokebox and the other end extending entirely through the firebox. This superheater and several others, as applied to locomotives, have the inherent defect of being inclosed by the cooler water or steam in the boiler, and therefore the superheat, if any is added to the steam, is later, to a considerable extent, returned to the boiler before reaching the steam chest.

The idea of this inventor was that hot gases from the furnace, coming directly in contact with the superheater elements, would rapidly deteriorate them and necessitate frequent renewals; for this reason he endeavored to protect them from direct action of the flame.

Stillman & Wilcox, of Westerly, Rhode Island, in 1859 were granted letters patent for a construction (see Fig. 9) in which

FIG. 10.

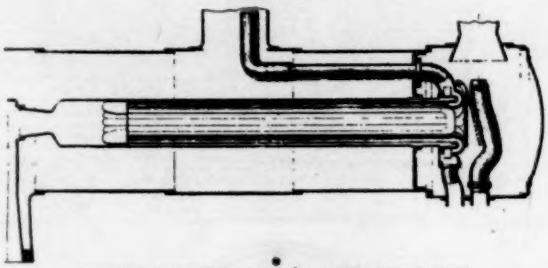


WEYER, LOREAU & CO. SUPERHEATER, 1869, FIRE TUBE TYPE.
The furnace gases are passed through a large return flue and in this flue there is a superheating coil. A hand-operated damper is used to control the flow of furnace gases.

a portion of the hot furnace gases are by-passed from the water tubes of the boiler to superheater elements encased in a jacket applied above the usual barrel of the boiler. In this case we see hot furnace gases passing directly to the elements. It is interesting, however, to observe that the inventor claims that by the use of this device he could regulate the flow of the products of combustion to the superheater by a damper, operated by the difference in pressure between the superheated and saturated steam, and that as early as 1859 it was recognized that this damper was, under certain operating conditions, desirable, if not necessary, just as the control of the furnace gases, either through the fire tubes of the boiler or through the large flues which contain the superheater elements, is an important feature of successful superheater practice to-day.

Weyher, Loreau & Company, of France, in 1869 obtained a patent covering a construction which has been little used, but which again illustrates the division of the furnace gases. A large flue contains the superheater elements in the form of a double coil. It is apparent from Fig. 10, and the one just referred to, that it was early recognized that at certain periods, depending upon the consumption of steam by the engine, the flowing gases had to be regulated in order not to overheat the superheater elements or to furnish steam of too high a temperature to the cylinders. Judging from the extent of the use of superheated steam upon locomotives, none of the early attempts were successful, because the design of the superheater did not overcome the obstacles presented in the operation of both boiler and engine, due to the higher temperature involved; and it was not until

FIG. 11.



SCHMIDT SUPERHEATER, 1897, FIRE TUBE TYPE.

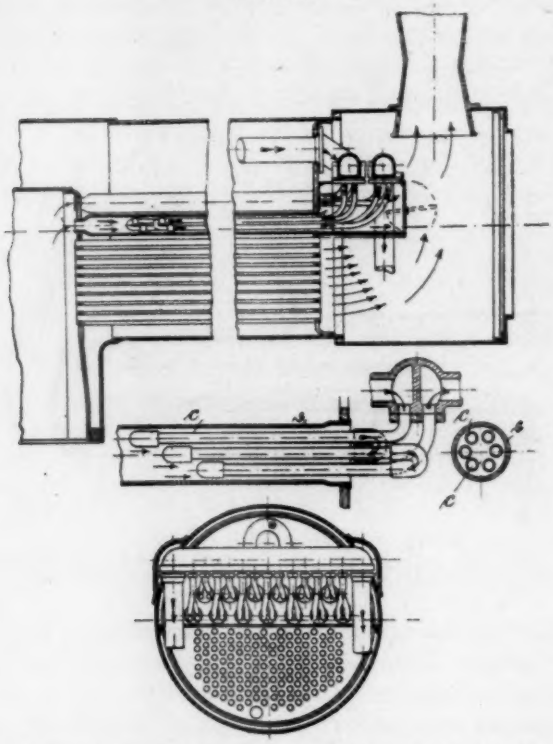
An early form of the Schmidt superheater now so much used. The large flue gave trouble from leakage and filling with cinders, and the arrangement was abandoned.

1897, when Dr. William Schmidt, of Germany, working in conjunction with Mr. Robert Garbe, of the Prussian State Railways, developed a superheater which laid the foundation for the extended application which we find to-day. Schmidt, having gained experience in applying superheated steam to stationary engines, paid particular attention to the perfection of lubrication and the maintenance of tight packing when using high-temperature steam, and in 1897 produced a design which was applied to a locomotive, as shown in Fig. 11. As already mentioned, this design was abandoned owing to the difficulty experienced in keeping tight the large flue in which was placed the group of superheater elements, as well as to trouble with this flue, due to its stoppage with cinders. His first change was to use a smokebox type of superheater in which a portion of the gases

from the furnace was passed through a large flue in order to provide sufficient heat to obtain a high temperature of the steam; this construction will be mentioned later under the smokebox type.

The invention of Schmidt and Thomsen in 1902 is illustrated in Fig. 12. A header for collecting and distributing the saturated

FIG. 12.



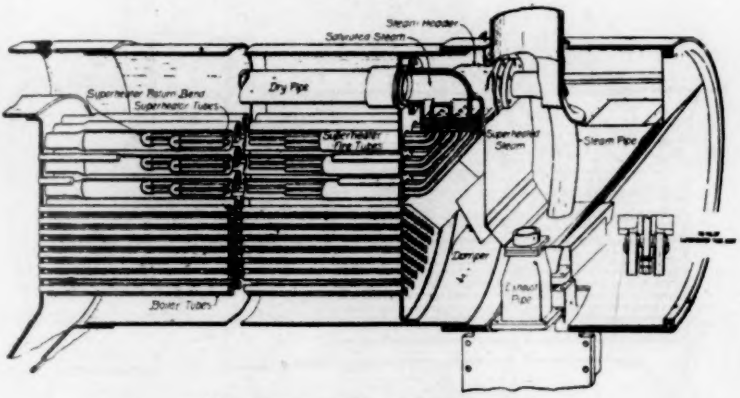
SCHMIDT & THOMSEN SUPERHEATER, 1902, FIRE TUBE TYPE.

A second form of the Schmidt superheater in which the elements are separated and placed in a number of large flues.

and superheated steam is employed, and attached to it are superheater elements enclosed in large fire tubes adjacent to and above the usual fire tubes of the locomotive boiler. A damper is provided in front of the flues containing the superheater elements, to confine, when desired, the hot furnace gases to the lower and smaller fire tubes of the boiler. The similarity of this construction to the one shown in Fig. 3, that by De Montcheuil in 1850,

is striking. All of the elements of the De Montcheuil design are found in the Schmidt construction excepting the damper and the combination saturated and superheated steam header in two distinct parts, for it will be noted that De Montcheuil carried his superheated steam down the sides of the smokebox rather than across the top. It was found with this construction that any desired superheat could be obtained by a proper proportion of superheater heating surface to water-heating surface, and therefore Schmidt obtained the high superheat of which he is a strong advocate. Not only did he obtain high temperatures, but by careful study of the proper means of lubrication and by special de-

FIG. 13.



SCHMIDT SUPERHEATER, FIRE TUBE TYPE.

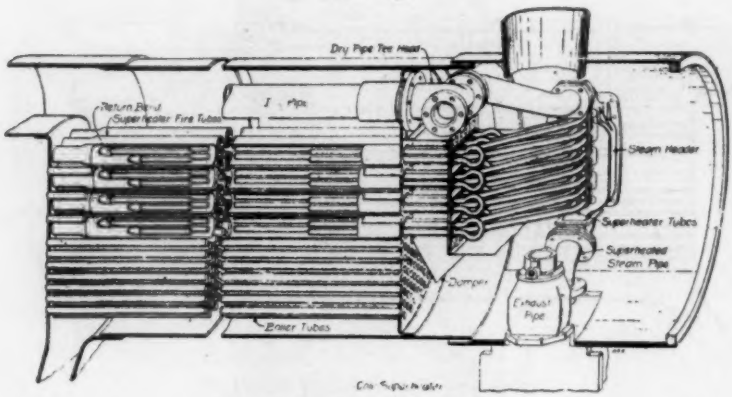
This shows the form of the superheater now in general use. It consists of a steam header and superheating elements, consisting of small tubes making two passages through the hot gases in a number of large fire tubes. There is a damper to check the flow of hot gases when steam is not flowing through the superheater.

signs of valve stem and piston-rod packings, as well as of valve and piston packings, he successfully used this highly superheated steam.

Fig. 13 illustrates again the Schmidt construction as used today in this country and in Germany and it is interesting to see that in this arrangement there is a combination casting for the saturated and superheated steam, and below the elements a damper. A detail of the superheater tube joint is also illustrated, as the perfecting of this joint was one of the difficulties encountered in the maintenance of this superheater, and the construction, as shown, largely overcame the trouble which had been experienced in maintaining the superheater steam-tight at the

header casting. It is seen from this figure that the gases from the firebox pass through both the boiler and the superheater fire tubes when the damper is open. When the damper is swung to a closed position the gases cannot pass through the superheater fire tubes, and thus a protection is afforded against overheating; the small tubes can convey all of the hot gases when the damper is closed. This damper is operated by a small steam cylinder which is actuated by the pressure in the steam pipe immediately above where it enters the steam chest, so that when the throttle is opened, and there is pressure in the steam pipes or steam chest, the damper opens, and when the steam is shut off at the throttle this damper closes by gravity and blocks off the flow of the

FIG. 14.



COLE SUPERHEATER, FIRE TUBE TYPE.

This superheater differs from the Schmidt in having a side header instead of a top header.

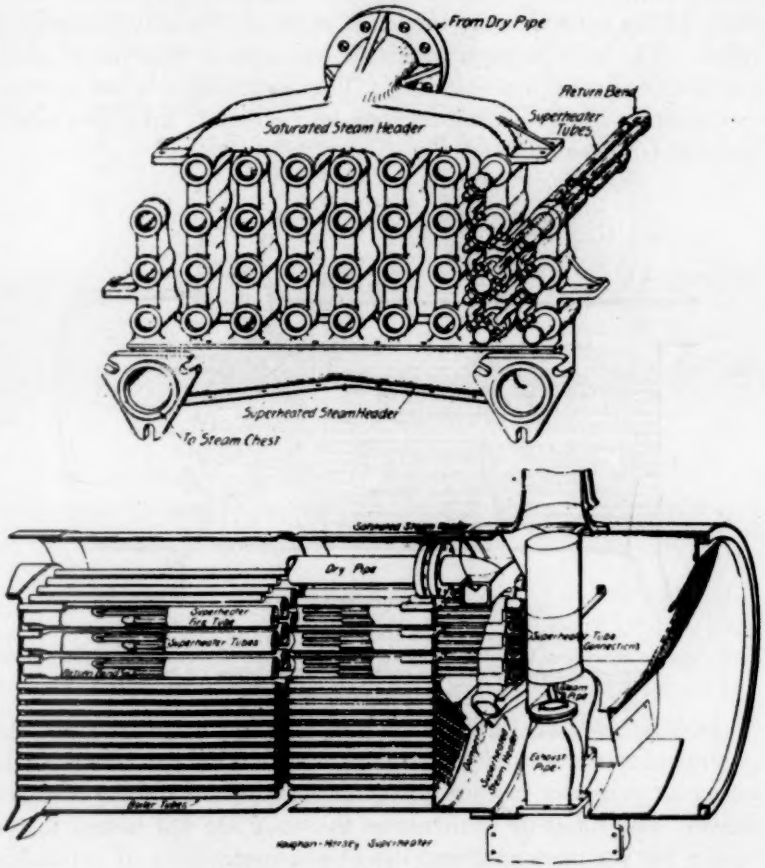
furnace gases through the fire tubes containing the superheater elements.

Following the success of Schmidt in maintaining good lubrication and packing with the use of highly superheated steam, Mr. F. J. Cole, of Schenectady, N. Y., brought out a side-header superheater which is shown in Fig. 14. A glance at this figure will serve to illustrate the construction, and it will be seen that the top header of the Schmidt device has been divided into two side headers to which are attached the superheater elements. They are attached by a different means, however, from that shown in detail in Fig. 13 of the Schmidt construction.

Mr. H. H. Vaughan, of Montreal, Canada, introduced and

has in operation a large number of locomotives equipped with the design shown in Fig. 15 and known as the Vaughan-Horsey superheater. Here again we have all of the essential parts found in the De Montcheuil, Schmidt and Cole construction, with the

FIG. 15.



VAUGHAN-HORSEY SUPERHEATER, FIRE TUBE TYPE.

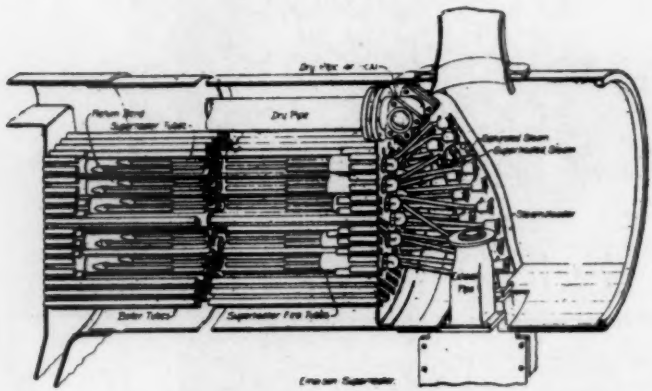
In this superheater all of the essential parts of the Schmidt construction appear. The header, instead of being above the elements, is in front of them. The superheater elements are connected to the header by a connection similar to a pipe union.

exception that the saturated steam header is in front of the tube sheet, instead of at the top or sides. The superheater elements are attached to the two separate headers by means of coupling nuts which are of a special design to provide against the exces-

sive heat of the gases at this point. The early introduction of highly superheated steam on the Canadian Pacific Railroad was accomplished by the design as shown in this figure.

The Emerson superheater as applied upon the Great Northern Railway is illustrated in Fig. 16. In this construction the superheater elements are fastened to the headers formed by the steam pipes in the smokebox by the usual method of expanding with a roller. The hole through which the expander is inserted is afterwards closed with a screw plug. The superheater is but another modification of the prevailing type in the details involving maintenance features.

FIG. 16.

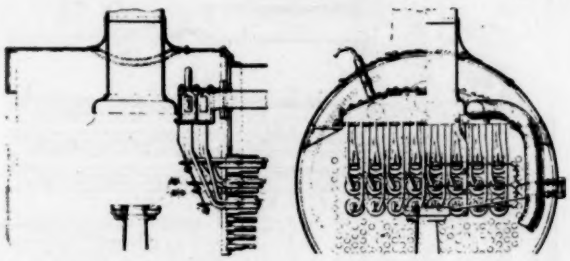


EMERSON SUPERHEATER, FIRE TUBE TYPE.
In this form of superheater the steam pipes on each side of the smokebox are used as headers, and the elements are connected by expanding the tubes.

In England, Mr. J. C. Robinson is using a superheater, the general construction of which is shown in Fig. 17. Here again we see a top header casting for both the saturated and superheated steam. The tubes or elements in this case are not bolted to the header but are prossered into it with the usual form of expander. The interior of the header is accessible by the removal of cover plates. A feature peculiar to this design is the manner in which the gas flow from the flues containing the superheater elements is stifled when the locomotive is not working. This is accomplished by steam jets which are introduced at the front end of the flues. The flow of steam from these jets, when the throttle

is closed, overcomes the vacuum of the smokebox and blocks the passage of the hot furnace gases through these tubes. It is claimed that the application of these steam jets aids in reducing the quantity of cinders which tend to collect about the superheater elements in the large fire tubes.

FIG. 17.

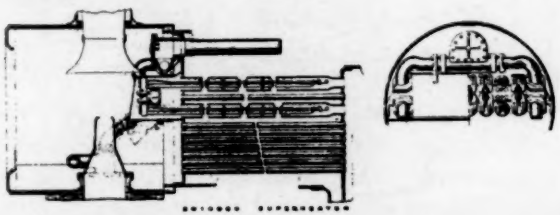


ROBINSON SUPERHEATER, FIRE TUBE TYPE.

This is an English superheater. The elements are connected to the header by expanding the tubes. Instead of a damper, there are steam jets which baffle or check the flow of gases when the superheater is out of service. These steam jets also serve to blow out the cinders and dust from the elements.

On the Great Western Railway of England a number of locomotives have been fitted with the Swindon superheater as shown in Fig. 18. Here again the usual construction is evident, with

FIG. 18.



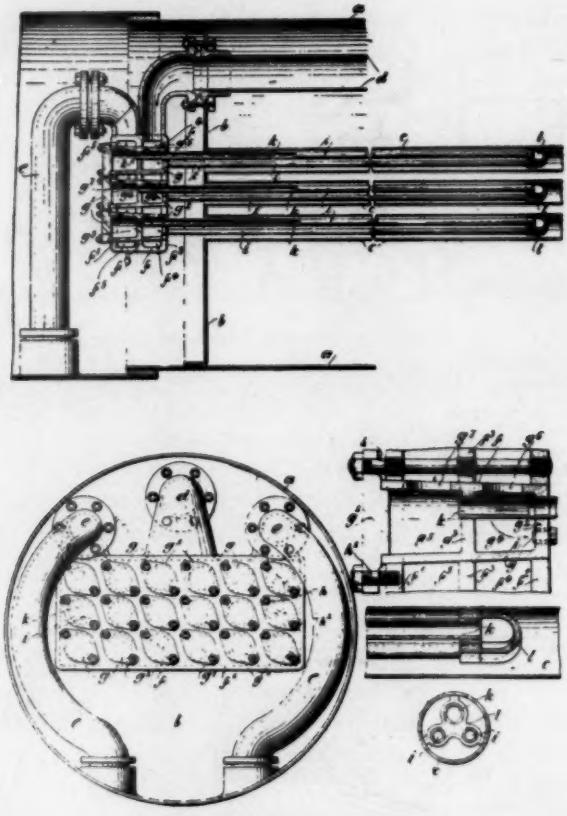
SWINDON SUPERHEATER, FIRE TUBE TYPE.

This is an English superheater. The header is in front of the elements. Each of the elements consists of three double tubes which are expanded into the heater.

the exception that a change is made in the manner of fastening the elements to the header. In this design the elements consist of a set of three double tubes which are expanded into a casting of horse-shoe shape, one side of which is connected with the

saturated portion of the header and the other receives the superheated steam. A damper is provided at the bottom of the box through which the flowing gases pass from the superheater elements.

FIG. 19.



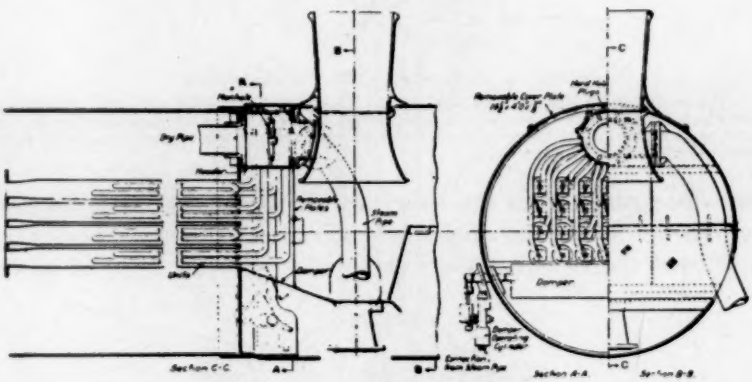
VAUCLAIN SUPERHEATER, FIRE TUBE TYPE.

In this superheater the header is in front of the elements. The elements are expanded into tapered cylindrical castings, and these castings are inserted into the header. Each element consists of one large tube with two smaller return tubes.

An illustration of a patent granted to Mr. S. M. Vauclain, of Philadelphia, Pa., in 1912, is shown in Fig. 19. The arrangement of the elements in the fire tubes is novel, in that the steam from the vertical saturated steam header first passes through one

tube and returns to the header through another tube. The method of fastening the elements to the header seems to have been devised with the idea of reducing to a minimum complications in the construction of the header casting, and in order to accomplish this a number of additional joints are required. The superheater element tubes are attached to the header casting by expanding the tubes in the manner generally practised in boiler construction, and bolted caps are provided for the openings through which tools are inserted in the tubes.

FIG. 20.



FOSTER SUPERHEATER, FIRE TUBE TYPE.

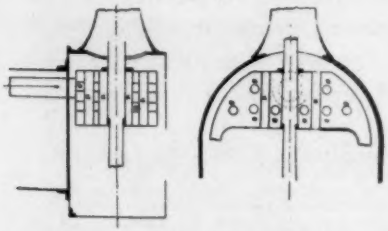
In this superheater the header consists of a steel plate drum into which the elements are expanded. The tube ends can be fastened without entering the smokebox or interfering with the internal arrangement of it. There is the usual damper for controlling the flow of gases.

The Foster superheater, which has been devised for the purpose of reducing the number of parts and to overcome difficulties in maintaining the superheater header casting, is shown in Fig. 20. In this construction a steel drum is substituted for the cast saturated and superheated steam header and the element tubes, by a series of bends, are introduced into the drum and fastened by the usual boiler tube expanding tool. This construction permits of the fastening of these tubes without interfering with the internal arrangement of the smokebox as applied to a locomotive. A special damper for controlling the flow of hot gases from the furnace, as in most of the other modern superheaters, is employed.

SMOKEBOX TYPE.

Next in importance to the fire tube type is the smokebox type, which was at one time looked upon with great favor, as it was thought that a superheater of this type would utilize the heat in

FIG. 21.

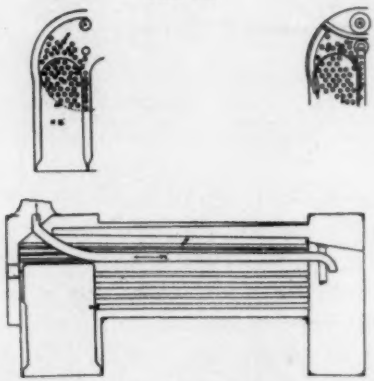


HAWTHORN SUPERHEATER, 1839, SMOKEBOX TYPE.

The smokebox superheater is an attractive arrangement, as there is a possibility of utilizing heat which would otherwise be lost. It introduces, howerever, an interference with the flow of gases, and this has limited its use. It will be noted that this type was suggested at a very early date in the history of superheating.

the waste gases from the boiler which would otherwise be lost by passing out through the stack. Trials of this type, however, developed the fact that the interference with the flow of gases

FIG. 22.



HAWTHORN SUPERHEATER, 1839, SMOKEBOX TYPE.

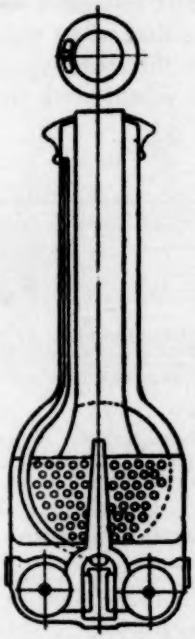
The boiler has a return tube in which the superheater is located. It was suggested that this arrangement be used either separately or in conjunction with the smokebox superheater.

in the smokebox, together with the accumulation of cinders, reduced the available output of the locomotive, and therefore it could not be considered as desirable as the fire tube type.

A complete description of a test of a freight locomotive, equipped with a superheater of this type and tested at the Locomotive Testing Plant of the Pennsylvania Railroad, can be found in their Bulletin No. 13, entitled "Smokebox Superheater."

R. & W. Hawthorn, contemporaries of Trevithick, in 1839 had a patent issued to them in which one arrangement proposed

FIG. 23.



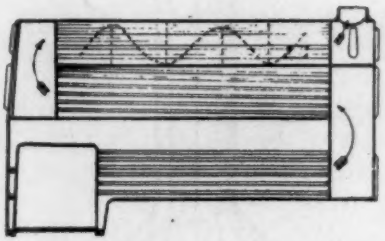
COCKERILL SUPERHEATER, 1848, SMOKEBOX TYPE.

In this Belgian superheater the elements are in the smokebox and extend to the top of an enlarged smoke stack.

the superheating of the steam entirely within the smokebox. The apparatus is shown in Fig. 21, the steam passing through a pressure tight steam box, and the gases from the furnace, after leaving the tubes, flow both vertically and horizontally through tubes in this steam chamber. Another arrangement proposed by them is shown in Fig. 22, in which the apparatus consists of return fire tubes which occupy a space above the water tubes of the boiler, and it was proposed that this arrangement be used

either separately or in conjunction with smokebox superheating. It is thought that this invention originated not so much from the work of Trevithick in 1832 as from the suggestion made by Joseph Perkins, who in February, 1837, conceived the idea of employing superheated steam in locomotives. A paper by Perkins establishes the fact that the essential principles of superheating were then known. According to Perkins's patent, he mixed with the superheated steam a certain proportion of water to obtain, as he said, a steam in the perfect state and from his data he concludes " experience shows that when water is heated in tubes entirely in contact with fire, the steam generated possesses greater, or less, temperature." It would seem that the Hawthorn inven-

FIG. 24.



COWPER SUPERHEATER, 1851, SMOKEBOX TYPE.

This is a superheater arrangement to recover heat in the waste gases, superheating by means of the gases as they flow through a third pass outside of the boiler.

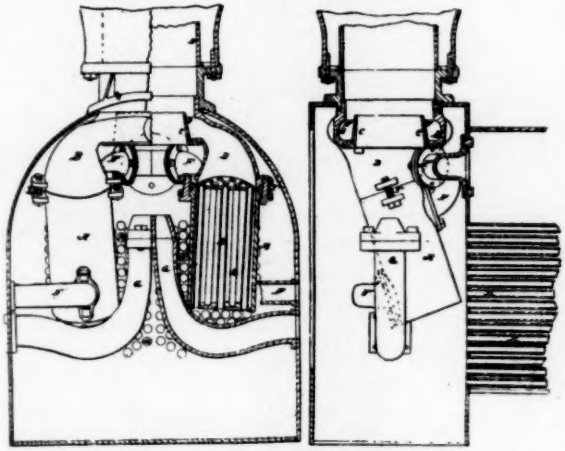
tions were intended to provide a means of obtaining the effect suggested by Perkins.

Nine years later, or in 1848, there were applied to six locomotives, built by the firm of John Cockerill in Belgium, superheaters arranged around the smoke stack, as shown in Fig. 23. By the arrangement employed the steam in its passage to the cylinders was superheated from the waste gases of the boiler, and in order to provide insulation to retain such heat as the steam collected, material of felt and wood was inserted between the superheater and the stack. This superheater also provided for a very large capacity in the steam chamber. It was stated in the description that " this arrangement has demonstrated that by the generation of the steam, due to the high steam pipe, the steam entered the cylinder entirely dry."

Following the work in Belgium, Chas. Cowper in 1851 ob-

tained a patent for an invention very similar to that of Hawthorn, in which he makes use of the waste gases from the boiler, superheating by means of these waste gases in the third pass toward the stack, the gases having made the second pass in the boiler through fire tubes. This arrangement is shown in Fig. 24 and is merely a modification of the scheme proposed by Hawthorn and shown in Fig. 22, requiring the flowing gases to pass forward in their third pass to the stack of the locomotive. It is interesting to observe, however, that baffles were placed in the super-

FIG. 25.



MARTIN SUPERHEATER, 1860, SMOKEBOX TYPE.

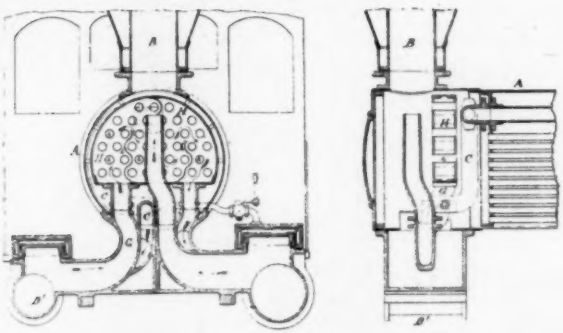
This superheater consists of two vertical drums in the smokebox. All of the gases are required to pass through tubes in these drums, and the drums form a part of the steam pipes.

heater chamber, in order to increase the length of passage of steam in flowing from the throttle to the steam chest. This same arrangement was later employed in the barrel type of superheater, which Cowper was the first to propose and which is shown in Fig. 34.

A much more elaborated installation is shown in Fig. 25, suggested by J. Martin in 1860. This arrangement differs from other attempts at smokebox heating in that the superheater chambers are of the drum type and make up a portion of the steam pipes connecting the throttle and steam chest. All of the gases of combustion were required to pass through the tubes of the superheater steam drums.

The tubes in the drums of the Martin construction were vertical, whereas in 1873 W. S. Hudson, of New Jersey, proposed a similar scheme in which the tubes for the passage of gases are horizontal and directly in front of the tube sheet. This ar-

FIG. 26.

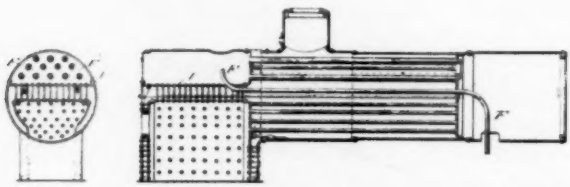


HUDSON SUPERHEATER, 1873, SMOKEBOX TYPE.

This superheater consists of horizontal tubes in the smokebox. It is the first instance of a superheater designed to heat the steam between the high and low pressure cylinders in compounding.

rangement is shown in Fig. 26, and is of particular interest as it shows one of the earliest arrangements for heating the steam when compounding, in that the heater is used only for drying the steam after it has left the high-pressure cylinder, but while

FIG. 27.



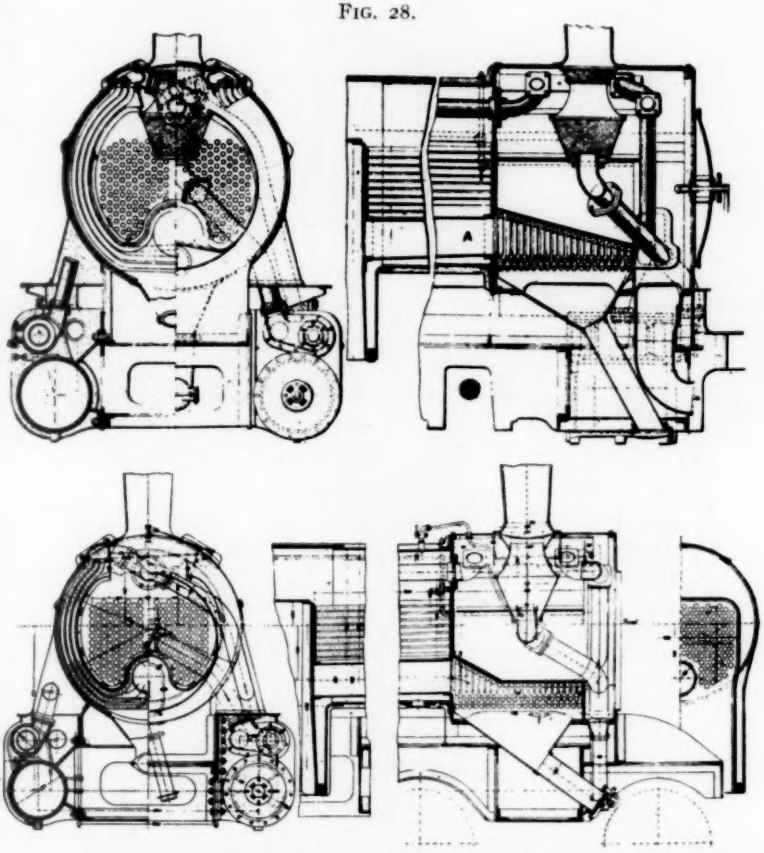
COVENTRY SUPERHEATER, 1885, SMOKEBOX TYPE.

This arrangement of superheater is very similar to that proposed by Hawthorn in 1839. Superheating is accomplished by returning the fire tubes through the steam space of the boiler.

it is still retained in the receiver, the receiver in this case being the smokebox superheater. In the claim of his patent, however, he does not confine the use of his superheater to superheating purposes only.

Chas. B. Coventry, of Chicago, in 1885 secured letters patent upon a waste gas superheater for locomotives, as shown in Fig. 27. This arrangement is but a slight modification of that proposed by Hawthorn in 1839 and consists in a change in form of

FIG. 28.



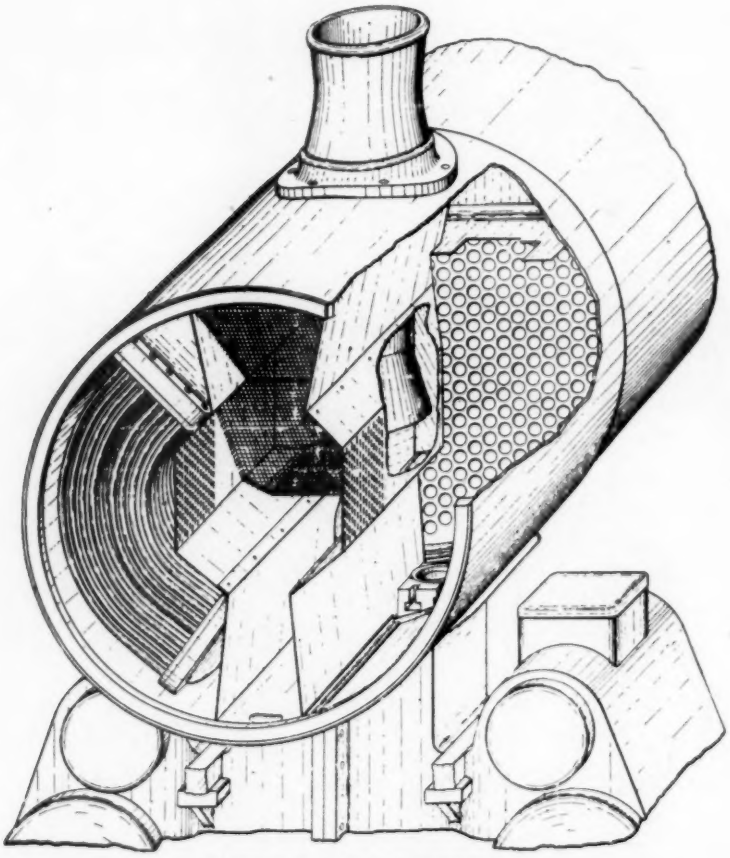
SCHMIDT SUPERHEATER, 1898, SMOKEBOX TYPE.

These two drawings show the second arrangement adopted by Schmidt. He endeavored to obtain a high superheat by using hot gases from the firebox, but with the superheater entirely within the smokebox. This superheater was extensively used, but has been superseded by a later form.

the roof sheet of the firebox to form a portion of the smokebox chamber. Difficulties involved in the boiler construction and maintenance precluded any use of the suggested modification in view of the small amount of superheat derived.

As already mentioned in reference to the work of Schmidt in the development of superheaters, the second form proposed by him was of the smokebox type as shown in Fig. 28. This he developed in 1898 after the trouble experienced with his first

FIG. 29.



BALDWIN SUPERHEATER, SMOKEBOX TYPE.

This superheater consists of two banks of tubes which form part of the steam pipes in the smokebox. The gases are required to flow between the tubes by means of baffle plates. A moderate degree of superheat is possible with this arrangement.

superheater, which was shown in Fig. 11. This early form developed leaks in the large flue and a difficulty in keeping the small superheater tubes free from an accumulation of cinders. In this later arrangement a portion of the hot furnace gases are

carried through a large flue in the boiler and then through a cast iron chamber containing a nest of tubes which convey the steam between the throttle and the steam chest. The plan did not contemplate the production of low-temperature superheat, and for this reason the construction can hardly be called a typical waste gas or smokebox superheater, as is to be observed by reference to Fig. 28. The hot gases, after passing around small superheater tubes, are discharged at the top into the smokebox and thence out of the stack.

A low-temperature superheater of the smokebox type in which all of the gases, after they have left the fire tubes of the boiler, were forced to sweep past small superheater elements forming a portion of the steam pipe, was proposed by Mr. S. M. Vauclain of the Baldwin Locomotive Works and tried upon the Pennsylvania Railroad. This arrangement is shown in Fig. 29, and the results obtained with it have been reported in Bulletin No. 13 issued by that road. This superheater was also applied to a number of locomotives by other railroads in this country, but owing to its general effect upon the locomotive as a whole, as already mentioned, has been discontinued.

Directed by two vertical partitions the gases first pass around the smokebox walls, then return to the central portion of the smokebox and from this point are exhausted from the stack.

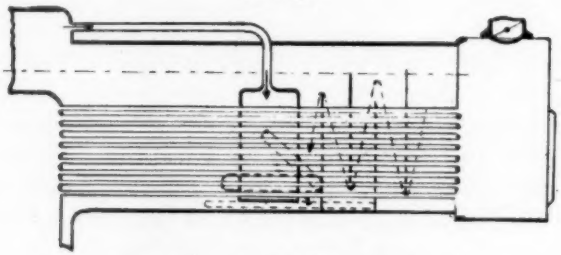
BARREL TYPE.

Quite a different form of superheater, and of very simple construction, is that known as the barrel type, one of the earliest forms being shown in Fig. 30; the superheater in this case consists of a superheating box within the boiler and surrounding the middle part of the fire tubes. This box is usually composed of two tube plates through which the boiler tubes pass. Saturated steam from the boiler is admitted to this partitioned superheater box and from it is conducted to the steam cylinders. The superheat gained by the steam in this box is somewhat decreased during its passage to the cylinders, and this arrangement does not provide any means for keeping the superheater box cool when the throttle is not open. For these two reasons it apparently has not met with great favor. Fig. 30 represents what was proposed by Cowper in 1851. In addition, Cowper proposed that the feed water should enter the boiler at a point near the front tube sheet

and be baffled through a series of compartments in succession as shown.

In 1855, John Ermorine, of Lyons, France, suggested a scheme which is shown in Fig. 31. In this case the superheater

FIG. 30.

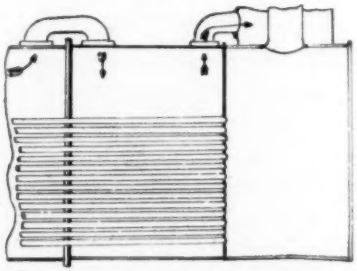


COWPER SUPERHEATER, 1851, BARREL TYPE.

This is an early form of the barrel type superheater, where the superheater consists of a box surrounding a part of the fire tubes. It causes an intermediate degree of superheat between that possible with the fire tube and smokebox types.

box was moved forward in the barrel so that the front wall of the superheater formed the front tube sheet. By this arrangement less loss in superheat in the passage from the superheater to the steam chest is encountered, but the arrangement only provides for a low degree superheat.

FIG. 31.



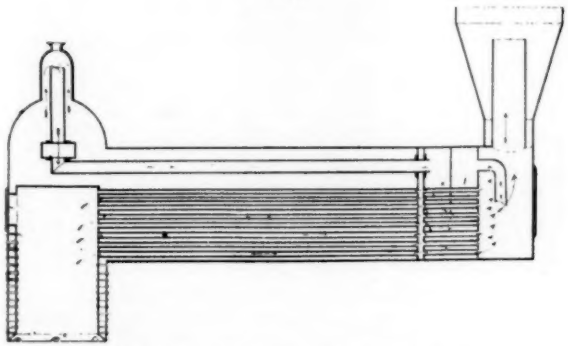
ERMORINE SUPERHEATER, 1855, BARREL TYPE.

In this barrel type superheater the smokebox end of the tubes is used, the forward tube sheet forming part of the superheater box.

In 1863, Benjamin Crawford, of Pittsburgh, Pa., obtained letters patent for an arrangement similar to the Ermorine, but with an improvement in the form of a baffle plate within the superheater box to cause the steam to pass to the lower tubes before it could leave the superheater, and thus obtain higher

superheat from a given amount of superheater heating surface. His superheater is shown in Fig. 32. The back wall of the superheater box was independent of the front tube sheet of the boiler.

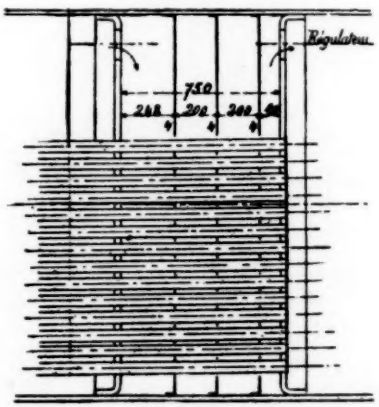
FIG. 32.



CRAWFORD SUPERHEATER, 1863, BARREL TYPE.

This superheater is very similar to the Ermorine, but it resembles more nearly the smokebox type, as it has a double tube sheet at the rear end.

FIG. 33.



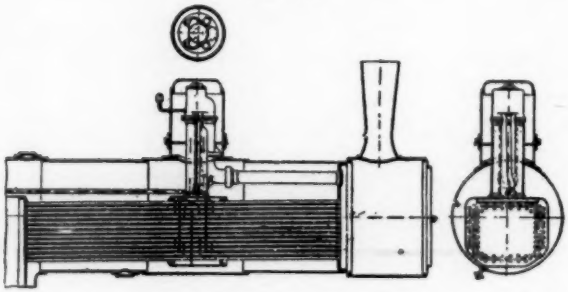
CLENCH-KING SUPERHEATER, 1896, BARREL TYPE.

This superheater is very similar to Crawford's, shown in Fig. 32. It has, however, more baffle plates.

In 1896, Clench-King, of France, designed a superheater arrangement quite similar to that of Crawford, with the exception that baffle plates are introduced into the superheating box and a simplification of the tube sheets is made. Substantially,

however, the two constructions are quite similar and produce only a moderate superheat. The Clench-King superheater is shown in Fig. 33.

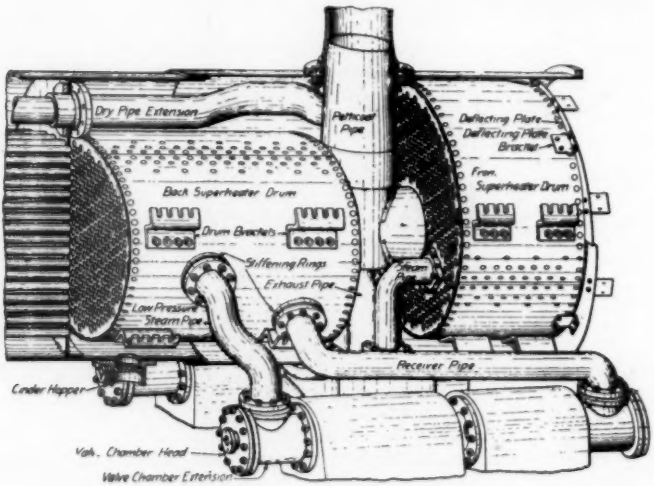
FIG. 34.



PIELOCK SUPERHEATER, BARREL TYPE.

This is a form of the barrel type which has been extensively used. The superheater is located about midway in the length of tubes and produces an intermediate degree of superheat.

FIG. 35.



JACOBS SUPERHEATER, BARREL TYPE.

This superheater consists of drums arranged in a manner very similar to that of Crawford's as shown in Fig. 32. In this illustration an arrangement of double superheater is shown for use in compounding, the steam being heated between the high and low pressure cylinders.

In Germany, at about this time, the Pielock superheater was introduced. It is located in the boiler barrel (see Fig. 34) in a manner similar to that proposed by Cowper and with the baffle

arrangement suggested by Crawford. This superheater was applied to a locomotive built for the Hannover Directorate of the Prussian Railway Administration and tested by the Pennsylvania Railroad on its Locomotive Testing Plant at the Saint Louis Exposition. A report of this test, under the title "Locomotive Tests and Exhibits, 1904," was published by the Pennsylvania Railroad. The tests indicated certain deficiencies in this form of superheater, as we have already noted.

Still another form of this general type of superheater was applied to a tandem compound locomotive built by the A. T. & St. F. Railway, the construction being shown in Fig. 35. Here it is seen that two steel drums are used for superheating the steam. The rear drum is made oval in cross-section to provide for the passage of the dry pipe connection to the other drum, these drums being placed directly before the front tube sheet of the boiler. The forward drum, which is circular in cross-section, is placed just ahead of the exhaust pipe and receives the saturated steam from the throttle. Within the drums are baffle plates to deflect the steam to the tubes contained within the drums. From the front drum the steam passes to the high-pressure cylinder, and the exhaust from this cylinder is received by the rear drum which reheats the steam for the low-pressure cylinders. The arrangement of a superheater of this character would seem to introduce serious interference with the passage of exhaust gases and cinders and would require a considerable vacuum in the smokebox in order to burn the coal in the firebox.

FIREBOX TYPE.

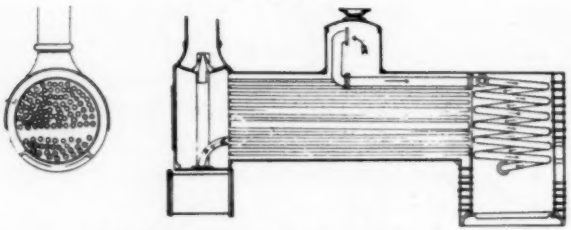
Little, if any, attention has been paid to the firebox type of superheater, and this is probably due to the difficulties experienced in providing a material which will withstand the heat of the firebox and remain steam-tight. This form of superheater has the distinct advantage over all others in that, for a minimum weight and the least heating surface, the highest possible superheat may be obtained. Constructive difficulties, however, seem to have been sufficiently great to have made this type impracticable with the materials now in use in boiler construction. It would seem, however, to have a future usefulness if materials can be found and so arranged that they will withstand high temperatures, and it is probable that future improvements of the

superheater will be directed toward this type or toward a modification of it.

As early as 1853 this construction was proposed by Andraud of Paris (Fig. 36), and the arrangement, as indicated by his drawings, shows the superheater entirely within the firebox, and placed above the fire in the form of a coil. This arrangement seems to be more practicable than that which was proposed by a Scotch engineer, John Hasel, in 1852, in which he placed a similar coil in the bed of fuel; it did not provide, however, for protecting the tubes when there is no steam passing through the superheater formed by the coil.

Estrade, a Frenchman, in 1882 proposed the arrangement shown in Fig. 37. This scheme consisted of a superheater located

FIG. 36.



ANDRAUD SUPERHEATER, 1853, FIREBOX TYPE.

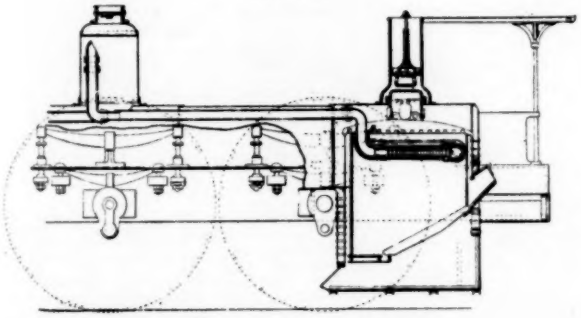
In this form the superheater has a coil of pipe in the firebox. No provision is made to protect the coil when no steam is flowing through it.

above the fire and immediately beneath the crown sheet of the boiler. The tubes conveying the steam were encased in an outer tube which was provided to protect them from excessive heat. The mechanical difficulties that have been mentioned as likely to occur in a boiler of this construction probably prevented its use.

For the same reason the construction proposed by Mossler & Stauffer in 1890 (see Fig. 38) never was applied to a locomotive. This arrangement, however, provides, in addition to the superheating heating surface in the firebox, a coil in the barrel of the boiler, and this coil made up the larger part of the water-heating surface for evaporation. A combination superheater of the fire tube and firebox type is shown in Fig. 39; this is an arrangement proposed by Schmidt in 1909. Here it is seen that the superheater elements are located in the fire tube, but instead of having a return wholly within the fire tubes, the

superheater is extended back and across the top of the firebox. This arrangement increases the length of passage of the steam within the superheater elements and at the same time subjects the elements to the much higher temperature of the firebox. A portion of the elements is protected by means of a brick arch baffle, shown directly beneath the tubes, and a chamber at the

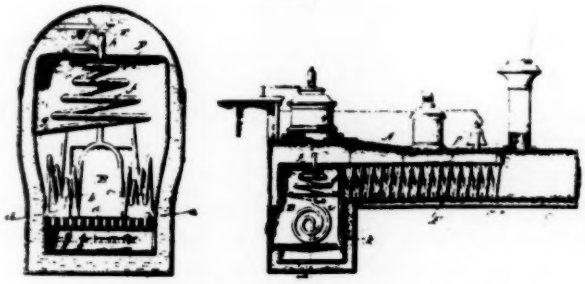
FIG. 37.



ESTRADE SUPERHEATER, 1882, FIREBOX TYPE.

This superheater shows a coil in the top of the firebox, but with a protective covering.

FIG. 38.



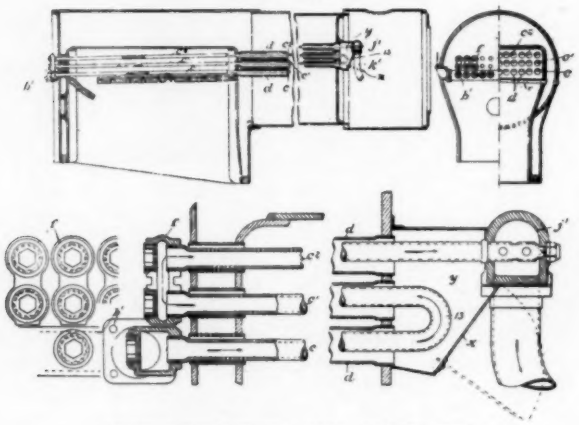
MOSSLER-STAUFFER SUPERHEATER, 1890, FIREBOX TYPE.

This superheater, which is merely a suggestion and was never used, provides superheating coils in the bed of fuel, above the bed of fuel and in the smoke flue.

front end provides for closing off the passage for gases through the large fire tubes containing the superheater elements when no steam is being used by the locomotive. It would seem that this arrangement should produce the highest degree of superheat with the least amount of heating surface. The scheme as proposed, however, provides for the collection of the superheated steam at the smokebox end of the superheater, and if such a collection

is made it is probable that there will be some loss in superheat in the passage of the steam from the firebox to the steam chest. If it would be possible to maintain the superheater tubes within the firebox, it would seem more logical to have the outlet for these elements at the firebox end of the boiler, the steam passing thence directly to the steam chest, rather than from the firebox

FIG. 39.



SCHMIDT SUPERHEATER, 1909, FIREBOX TYPE.

This superheater is a combination of the firebox and fire tube type. The superheater elements extend from end to end of the boiler, crossing the upper part of the firebox, where they are protected by the fire-brick covering.

to the smokebox and then into the steam chest. This course would undoubtedly prevent loss of some superheat, or an excess of superheating heating surface within the boiler tubes which is only available for superheating the steam after it has left the hot surfaces contained within the firebox.

PART II.

SUPERHEATER TESTS.

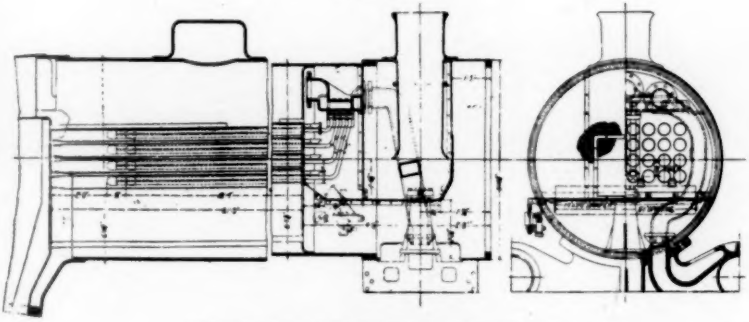
Having reviewed in outline the development of a practical form of locomotive superheater, it will be interesting to describe experiments with one of the fire tube type to determine the effect of superheat upon locomotive efficiency.

Before taking up the discussion of results, we should understand something of the form of the apparatus used and the method of conducting the tests.

The superheater used in all of the tests was a Schmidt superheater of the fire tube type, or an altered form of it. The normal, or what is called in this paper the standard superheater, consists of tubes arranged in groups or elements and located in large flues in the boiler. There were 32 elements in the locomotive used in the tests, one of the K2sa class of the Pennsylvania Railroad, and this standard superheater is shown in place in the boiler in Figs. 40 and 41.

Each superheater element is made up of four seamless steel tubes having an outside diameter of 1 1/16 inches and a thickness of 0.148 inch, all connected together by cast steel return

FIG. 40.



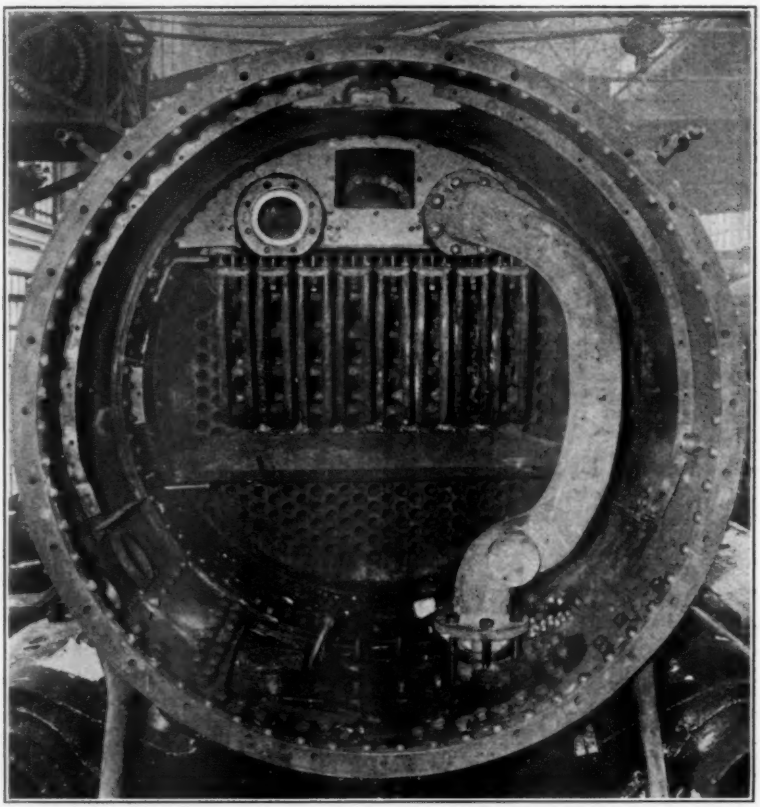
SUPERHEATER AND SMOKEBOX ARRANGEMENT.

The regular or standard Schmidt fire tube superheater, as applied to the boiler of the test locomotive. This locomotive has steam pipes inside of the smokebox. A later form has outside steam pipes which extend through the smokebox sides and connect directly with the steam chest.

bends to form a continuous tube or loop. The steam from the boiler enters the header in the smokebox, then flows into one of each of the thirty-two superheater elements, passing twice through the hot gases which surround the elements; that is to say, the steam flows to the firebox end of the boiler and then returns to the smokebox end and again flows back to the firebox end and finally to the superheater header, entering a part of the header partitioned off to receive superheated steam. The steam then passes directly to the cylinders. This and similar arrangements are called in this paper "two-pass" superheaters. The superheater elements are connected to the header by a ball-joint connection, the ends of each element being drawn up to the header and held in place by a single bolt.

To protect the elements of the superheater from overheating when there is no steam flowing through them, an automatic damper is provided in the smokebox, as shown in Fig. 40. This damper opens only when steam is flowing through the super-

FIG. 41.



SUPERHEATER AND STEAM PIPES, K2sa LOCOMOTIVE.

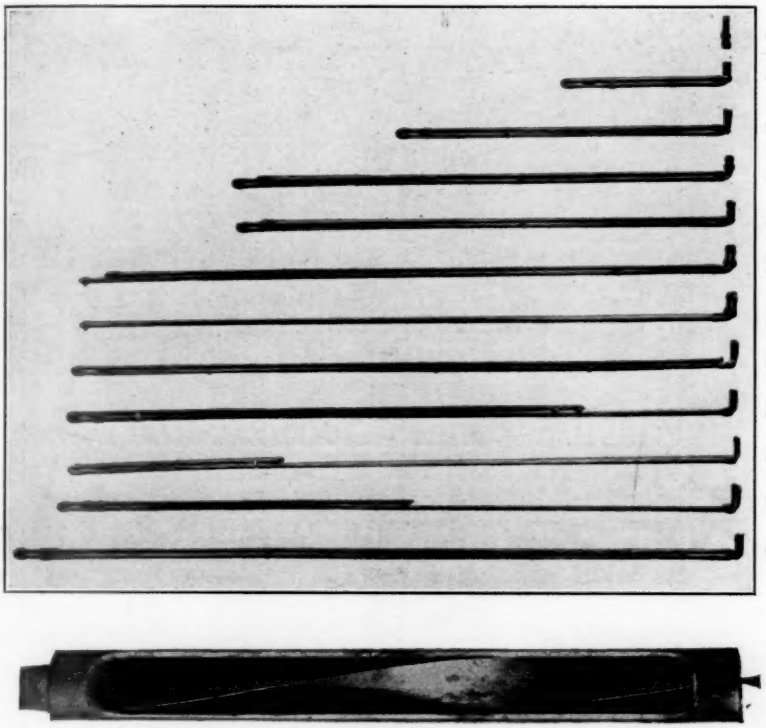
The standard superheater is shown in place. The deflector plates, damper, netting and a steam pipe have been removed.

heater, the steam pressure in the steam chest operating the damper piston.

At the firebox end the elements are supported by short lugs, the purpose of which is to raise the elements from the bottom of the flue so that the gases have a passage underneath.

The superheater elements take up a large part of the available space in the boiler flue, presenting a partial obstruction to the passage of the products of combustion through the flue, and the cinders in consequence accumulate about the elements, so that the flues must be cleaned at frequent intervals.

FIG. 42.



SUPERHEATER ELEMENTS.

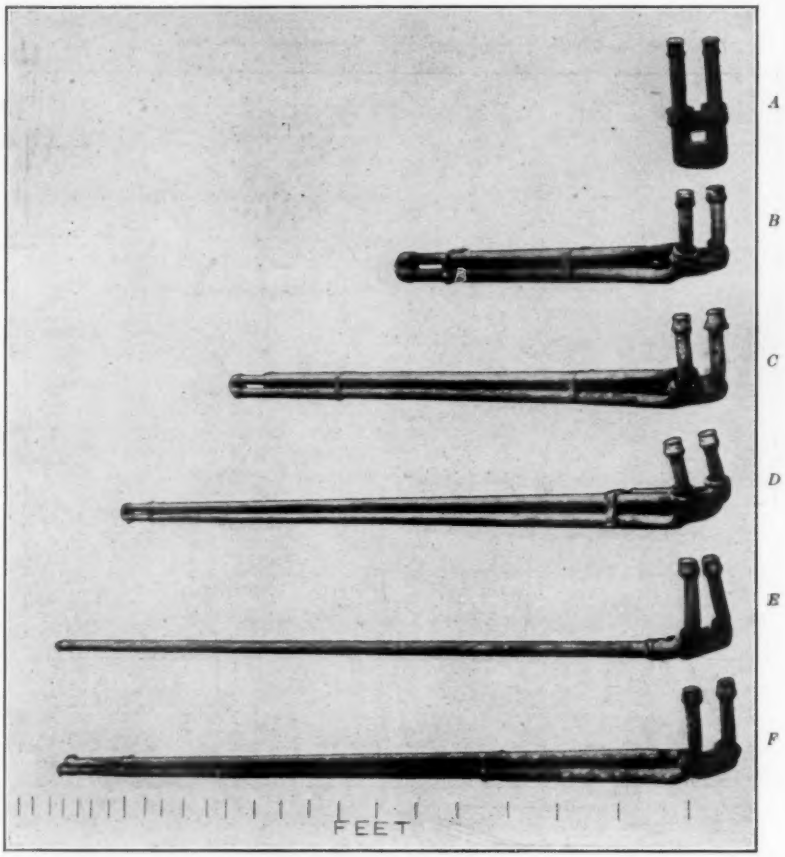
This view shows one element of each of the superheaters and indicates their relative length.

The enlarged view of a superheater tube shows a spiral or twisted plate which extended the whole length of each tube. This arrangement was used in Superheater I, one of the double-pass, ¾-length superheaters.

The superheater flues in the boiler have an outside diameter of 5½ inches at the front tube sheet, and for all of that portion through which the elements extend. Near the firebox tube sheet the flues are swaged down to an outside diameter of 4½ inches, this reduction being for the double purpose of permitting an

unrestricted circulation of water near the tube sheet, and also so that the fire area or flue opening at this point may be about equal to the opening for gases in the part of the tube containing

FIG. 43.



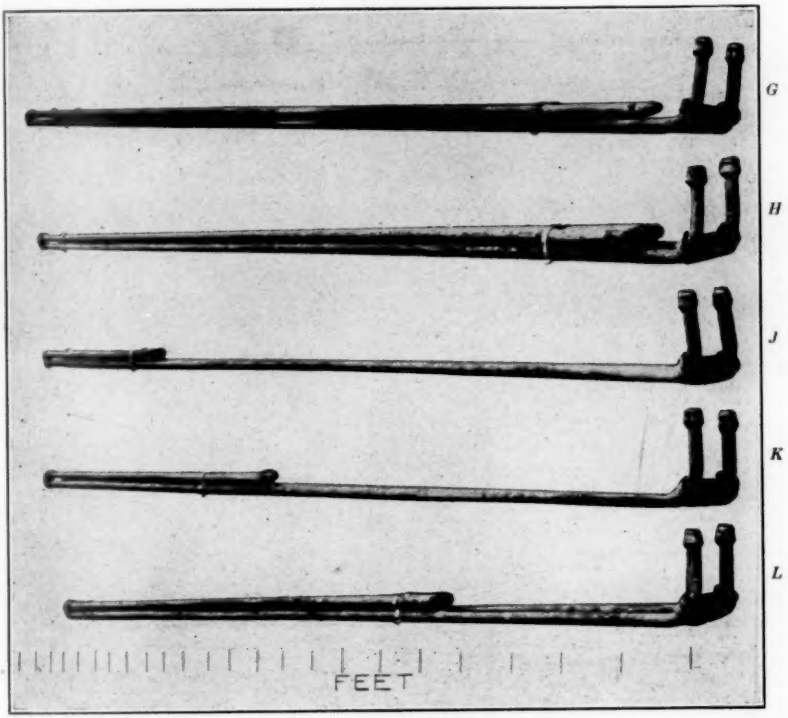
SUPERHEATER ELEMENTS.

Special or altered forms. *A*, short returns at header; *B*, ¼ length, 4 feet long; *C*, ½ length, 9 feet long; *D*, ¾ length, 14 feet long; *E*, single pass, 19 feet long; *F*, single pass dummy returns, 19 feet long.

the superheater element. The standard form of the superheater has 32 elements and a heating surface, including the header, of 989.3 square feet. The standard superheater is shown assembled in Figs. 40 and 41, and one element of it at *H* in Figs. 42 and 44.

In order to obtain different degrees of superheat without in any way changing the water-heating surface of the boiler or the engine conditions, different forms of superheater elements were used, maintaining the same superheater header and large flues. Fig. 42 shows the relative size of the different arrange-

FIG. 44.



SUPERHEATER ELEMENTS.

The standard and special or altered forms. *G*, extra length, 20 feet 5 inches long; *H*, standard, 19 feet long; *J*, ¼ return, 19 feet long; *K*, ½ return, 19 feet long; *L*, ¾ return, 19 feet long.

ments, while in Figs. 43 and 44 the details of the arrangements are clearly indicated.

In Fig. 43, *A* is simply an element at the header of which it might be said that when all of the elements are in place they form a smokebox superheater. *B* is a quarter-length superheater.

The superheater *C* is one-half length and *D* three-quarter length. *E* and *F* are of the same length as the standard, but of one pass.

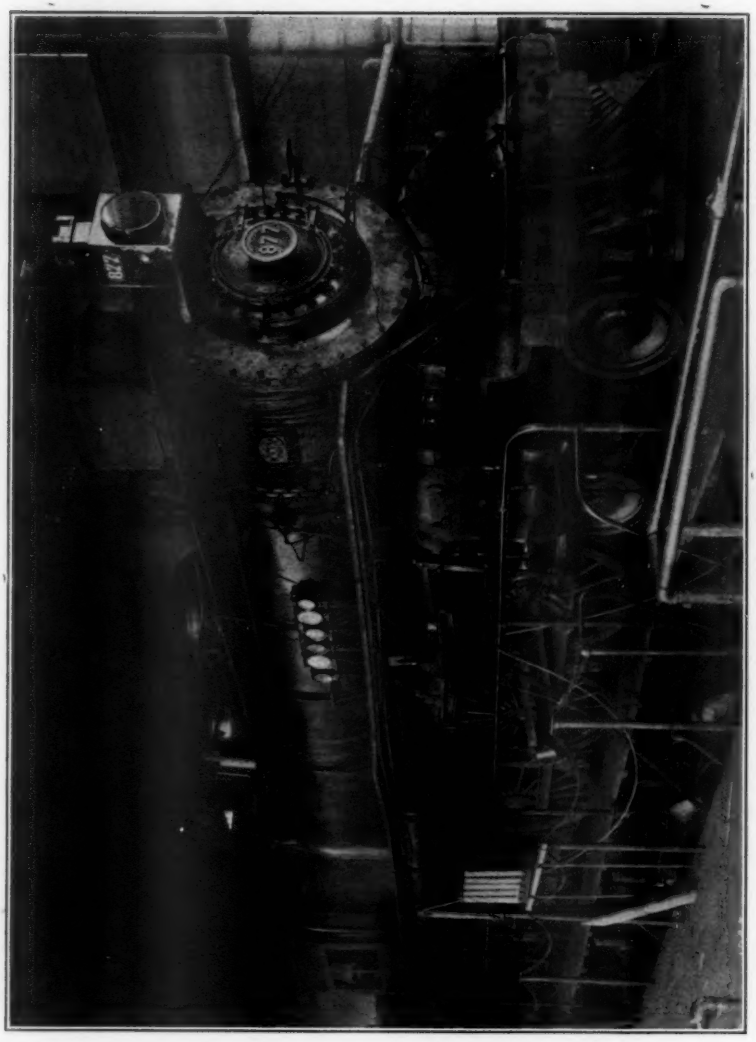


FIG. 45.

LOCOMOTIVE NO. 877, CLASS K2sa, IN POSITION FOR TEST.
Locomotive Test Plant, Pennsylvania Railroad Company, Altoona, Penna. The locomotive used in the superheater tests.

F, however, has additional pipes representing the second pass, but having no steam flowing through them. These dummy pipes were used with this single-pass superheater to make the gas

passage around the elements the same as with the standard arrangement. In Fig. 44, *G* is arranged in the same way as the standard, except that it is 17 inches longer for both passes, whereas *J*, *K* and *L* are similar to the standard arrangement *H*, excepting the return portion, which has a length one-quarter, one-half, and three-quarters that of the corresponding part of the standard superheater.

In addition to the foregoing, Fig. 42 shows a detail of a superheater of the three-quarter length arrangement of double-pass superheater, which had twisted plates inserted in the tubes of the superheater elements, the object being to cause a whirling motion of the steam so that its heat-absorbing action might be improved. An element is shown at *I* in Fig. 42.

DESCRIPTION OF LOCOMOTIVE.

One locomotive was used for all of the superheater tests; it was a class K2sa Pacific type passenger locomotive of the Pennsylvania Railroad with a brick arch in the firebox. This locomotive is shown in Fig. 45.

The general dimensions of the locomotive when equipped with its regular or standard superheater are given below.

Total weight in working order, lbs.	293,200
Weight on drivers in working order, lbs.	179,900
Cylinders (simple), inches	24 x 26
Diameter of driving wheels, inches	80
Heating surface in tubes (water side), sq. ft.	3436.37
Firebox heating surface, sq. ft., including arch tubes	208.02
Heating surface of superheater, fireside (standard)	989.32
Total heating surface (based on water side of tubes), including superheater, sq. ft.	4633.71
Total heating surface (based on fire side of tubes), including superheater, sq. ft.	4312.40
Grate area, sq. ft.	53.72
Boiler pressure, lbs. per sq. in.	205
Valves, type	12 in. piston
Valve, motion	Walschaerts
Firebox type	Wide, Belpaire
Number of tubes	202
Number of flues (superheater)	32
Outside diameter of tubes, inches	2.25
Outside diameter of flues, inches	5.5
Length of tubes, inches	250.08

Locomotive Test Plant, Pennsylvania Railroad Company, Altoona, Penna. The locomotive used in the superheater tests.

A complete efficiency test of this locomotive, when equipped with the standard form of the Schmidt superheater, was made before the special superheater tests were undertaken and the results are given in full in Bulletin No. 18, "Tests of a Class K2sa Locomotive,"[1] where a further description and drawings of the locomotive are shown.

METHOD OF CONDUCTING TESTS.

With each of the superheater arrangements, where it was possible, six tests were run, each having a length of one hour and a half; the cut-offs being 15, 25, 35, 45 and 50 per cent., except where the longer cut-offs could not be maintained. With some of the superheaters one test was made at a speed of 120 r.p.m. or 28 m.p.h., while all of the other tests were made at a speed of 240 r.p.m. or 57 m.p.h., thus the variable of speed of the locomotive was largely eliminated, and it may be generally assumed that the tests were all made at 57 m.p.h. The steam temperature was measured by means of a mercury thermometer inserted in a well in the steam passage of the cylinder saddle, at a point where the steam is entering the steam chest. The steam pressure was observed at this point and at the dome of the boiler by means of steam gages.

During the course of the tests the superheater elements were very carefully blown out with air at the end of each day, so that the conditions as to the superheater heating surfaces were apparently uniform and good.

While the tests were of one hour and a half in length, they have been recorded in the tables to appear as two tests, one of an hour duration and one of an hour and a half. It will be noted that the average for the latter part of the test or the last 60 minutes is, in most cases, slightly higher than for the longer time, for the steam temperature and superheat tend to rise slowly for perhaps three-quarters of an hour after the start of the locomotive (see graphical logs of tests, Figs. 55 and 56, for illustration of this effect). This effect may be due to the condition of the fire. The firebox temperature appears to increase during the whole time of a test run. At any rate, the results for

[1] Copies of this bulletin may be had upon application to the General Superintendent of Motive Power of the Pennsylvania Railroad, Altoona, Pa.

the latter part of the total time have been used in plotting all of the diagrams in the paper.

With the complete superheaters such as the standard, the half-return, etc., the superheat, a few minutes after starting, is high. Referring to the graphical log for test No. 3300.91, Fig. 56, the superheat at the beginning of the test is 228 degrees and it increased only 26 degrees during the one and one-half hours of running. In test No. 3300.50, with the half-return superheater, the superheat at starting is 240 degrees, increasing 38 degrees to a superheat of 278 degrees at the end of 90 minutes of running.

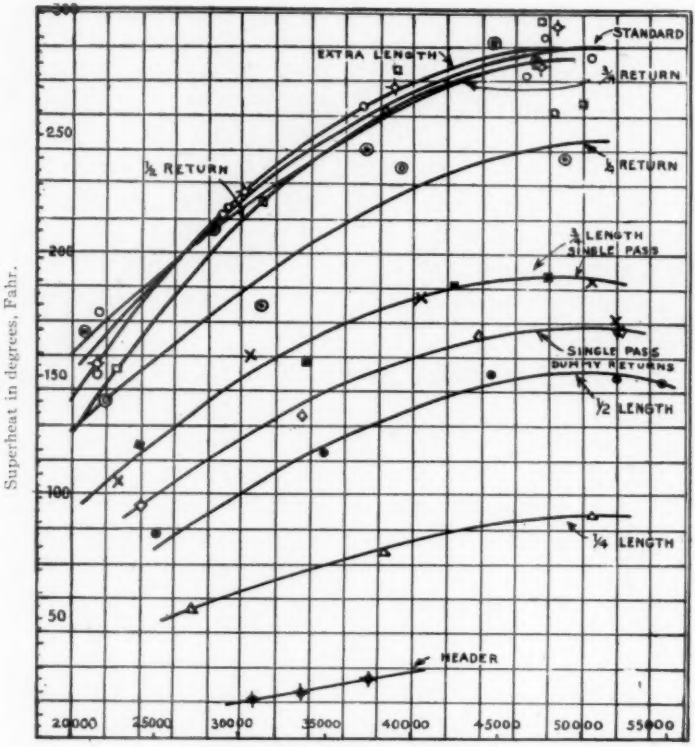
It was to obtain a range of superheat that the several superheater arrangements, full-length, three-quarter, one-half, one-quarter length and the short returns at header, were tried out. It was not expected that the shortened superheaters would develop an arrangement suitable or desirable for use in regular service; the only purpose in using them was to obtain wide variations in superheat.

RESULTS OF TESTS.

The Effect of Different Degrees of Superheat.—The evaporation and superheat for all of the superheater arrangements are shown in Fig. 46, and an evaporation between 21,000 and 55,000 pounds per hour was obtained, the superheater consisting of short returns at the header, and having a heating surface of about 50 square feet as compared with the standard, which has a heating surface of nearly 1000 feet, evaporates about 31,000 pounds of water per hour, and has an indicated horse-power of 1425, where, with the same cut-off and one of the extra-length superheaters, the evaporation is only about 21,000 pounds for this indicated horse-power. This effect is caused by the small superheat obtained with the short returns, requiring a greater weight of steam for the power produced. We find further that this small superheater will not evaporate more than 37,600 pounds per hour or but 70 per cent. of what the half-length superheater is capable. The small capacity of this header superheater is brought about by the fact that it does not extend into the large flues in the boiler. With these large flues open or unobstructed by the superheater elements, the boiler does not steam properly, the draft action is unchecked, and holes are made in the fire by the violent agitation of the draft. With the standard steam boiler, having all of the tubes of a small size or with the superheater

boiler having the superheater elements in the large flues, the draft pulsations are smoothed out and the fire is not so violently agitated. The small superheater gives a maximum superheat of but 26°.

FIG. 46.



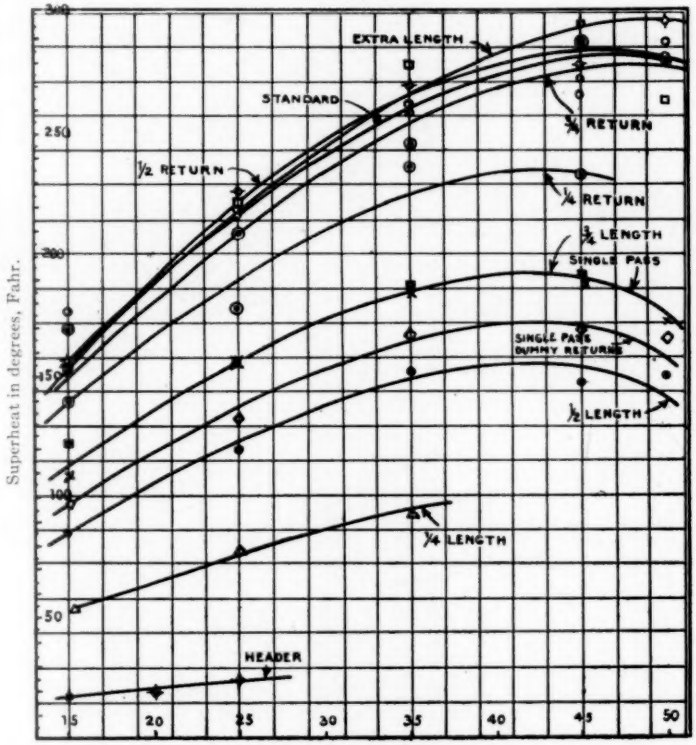
SUPERHEAT AND EVAPORATION

The superheat increases with an increase in evaporation up to about 50,000 pounds per hour. Above this evaporation there appears to be a falling off in superheat, probably due to the heavy fire that must be carried, and the fact that all of the coal fired is not being burned.

The superheaters of one-quarter, one-half, and three-quarter length show a regular increase in superheat produced, with the increase in length of superheater. The one-quarter length produces a maximum superheat of 90° and the three-quarter length a maximum of 190°. It is also shown by Fig. 46 that as the superheat is increased, the evaporation, when running at a short

cut-off, is decreased, and further, that the one-half length superheater gives the greatest evaporation that was obtained with any of the superheaters, about 55,000 pounds per hour. There would seem to be a best superheater length or area for maximum evaporation, but it must not be understood that this superheater, which is best for evaporation, gives the maximum horse-power.

FIG. 47.



SUPERHEAT AND CUT-OFF.

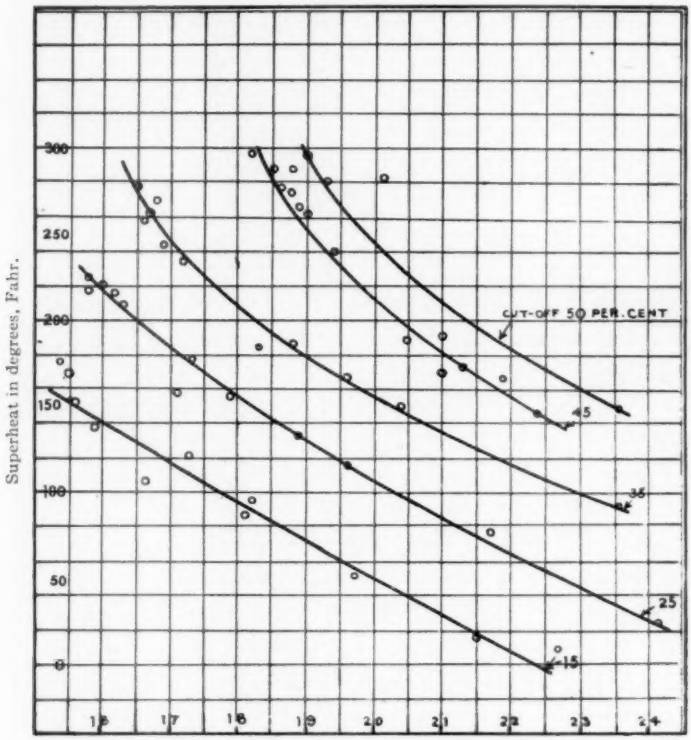
The superheat increases with the cut-off up to 45 per cent.; beyond 45 per cent. there is a falling off in superheat. (See Fig. 48.)

The extra length shows a higher superheat than the standard length, but there might be difficulties in the use of this long superheater where the ends come within a few inches on the firebox end of the flue, and the one-half return gives fully as much superheat; there would seem to be no advantage in the

extra length, with the disadvantage of increased friction due to the longer steam passage.

Referring now to Fig. 47, which shows superheat and cut-off, we find that the superheaters arrange themselves in very nearly

FIG. 48.



CUT-OFF AND STEAM PER INDICATED HORSE-POWER.

At the shorter cut-offs there is a uniform decrease in the water rate with each increase in superheat. As the cut-off is extended the water rate increases, but has a tendency to become more nearly constant with an increase in superheat. A water rate of 24 pounds is obtained with a superheat of about 30 degrees. If the superheat is increased to 220 degrees without a change in cut-off, the water rate is reduced to 16 pounds.

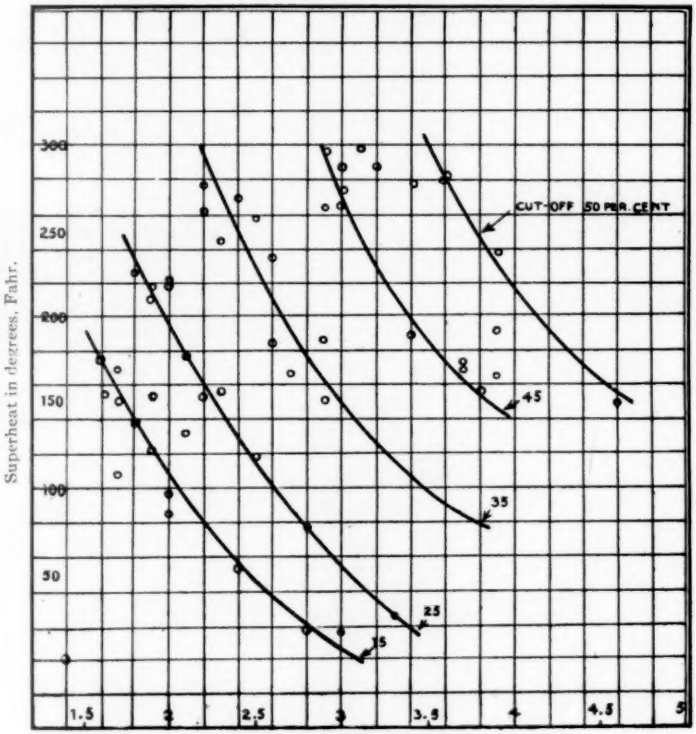
the same way as in Fig. 46, and this is to be expected because, on account of the constant speed, the evaporation is dependent almost entirely on the length of cut-off.

Considering now the economy resulting from the superheat we have in Fig. 48 the cut-off and steam per indicated horse-

power. This diagram expresses graphically the essential facts for which the experiments were made, and gives for the first time authentic data upon the economy due to superheat unobscured by other variables.

The points of this diagram do not indicate the arrangement of superheater, but show the effect of both the superheat and

FIG. 49.



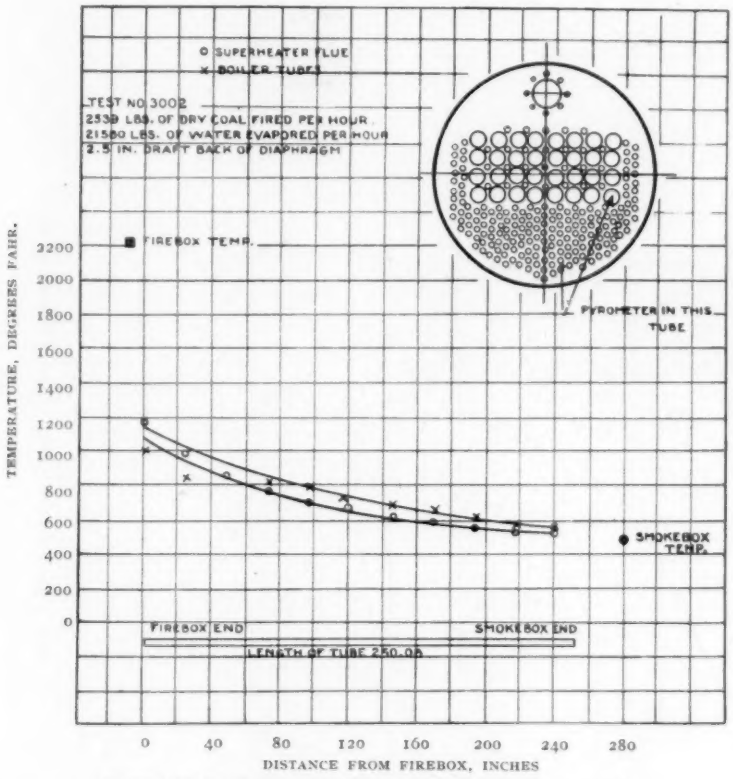
SUPERHEAT AND COAL PER HORSE-POWER.
Each increase in superheat shows a saving in coal.

cut-off on the economy in steam. We find from the diagram, which shows a superheat ranging from zero, or practically saturated steam, up to 300°, that for every increase in superheat, at every cut-off, there is a saving in steam, and that at 15 per cent. cut-off, at the speed of these tests, for every 20 degrees rise in superheat there is a reduction in water rate of one pound

per indicated horse-power hour. At 50 per cent. cut-off this increases to a requirement of about 40° rise for the same reduction in water rate.

With a cut-off of 15 per cent. and a superheat of about 70° we can obtain a water rate of 19 pounds per indicated horse-

FIG. 50.



TEMPERATURES IN THE SUPERHEATER FLUE AND BOILER TUBE.

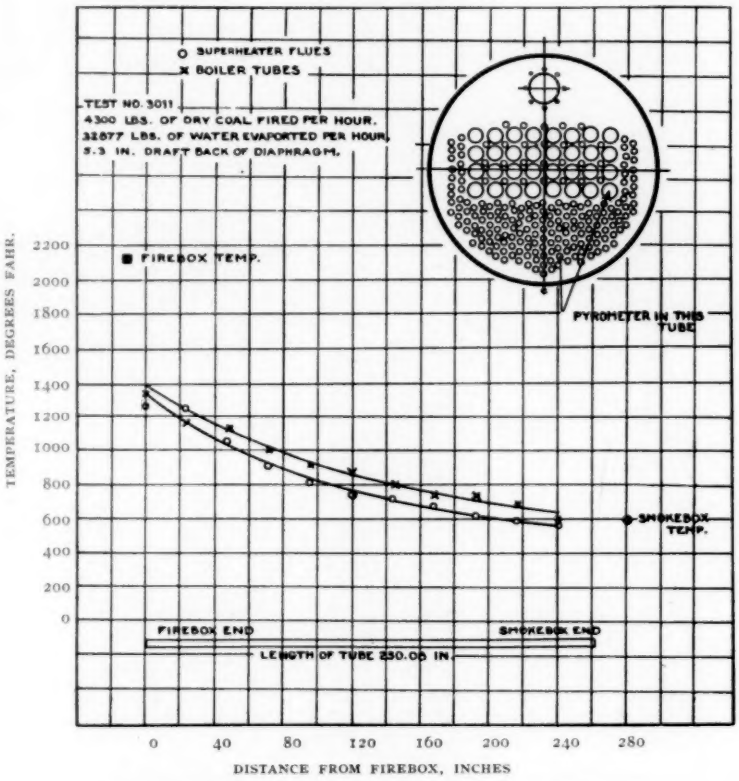
Temperatures at a coal rate of 2539 pounds per hour. The steam temperature is 572 degrees and is equal to the gas temperature at a point 170 inches from the firebox.

power hour, while if the cut-off is extended to 50 per cent. at the same speed, the superheat must be increased to 300 degrees so that the water rate will remain at 19 pounds. The very great importance of the length of cut-off is thus apparent, but even with the longest cut-off that is shown the water rate does not reach 24 pounds, or what may be called the minimum water rate for

saturated steam. It thus appears that superheat always shows a saving in steam if the cut-off does not exceed 50 per cent. Very similar conclusions may be drawn from Fig. 49, which shows the superheat, the cut-off and coal per horse-power hour.

Some time before these superheater tests were undertaken a

FIG. 51.



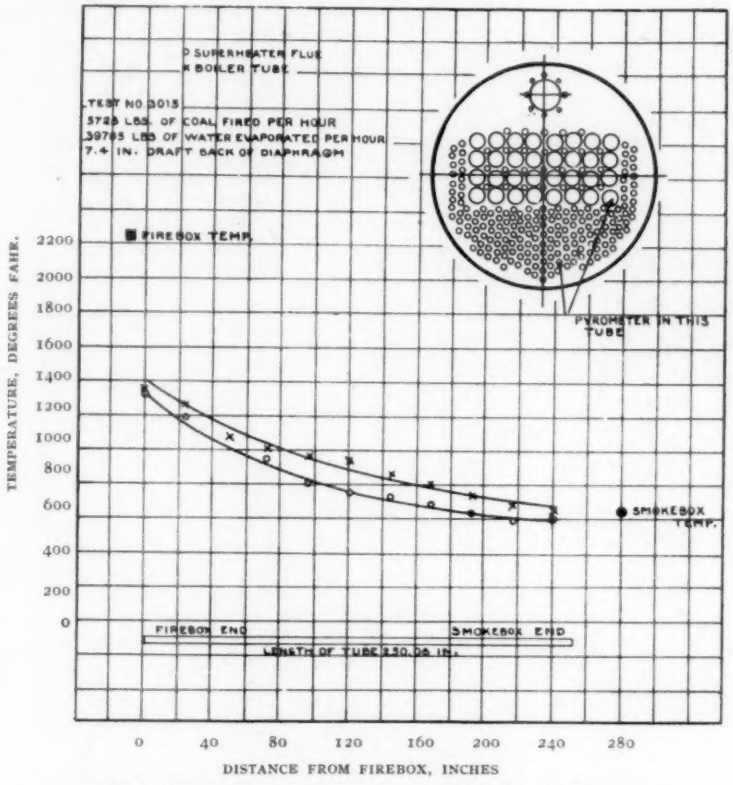
TEMPERATURE IN THE SUPERHEATER FLUE AND BOILER TUBE.

Temperatures at a coal burning rate of 4300 pounds. The steam temperature is 633 degrees and is equal to the flue temperature at a distance of 180 inches from the firebox.

series of efficiency tests with the standard superheater was made with this locomotive, and Figs. 50 to 52 show the temperature measurements in boiler tube and superheater flue made at that time. In Fig. 50 the temperature in the superheater flue is 1160° at the firebox end, falling to about 540° at the smokebox end.

The steam temperature for this test is 572°. It will thus be seen that at about 170 inches from the firebox the steam temperature equals the temperature of the gases, and there would be no gain by extending the superheater return any distance forward of this point. This return portion extends forward to a point 148 inches

FIG. 52.



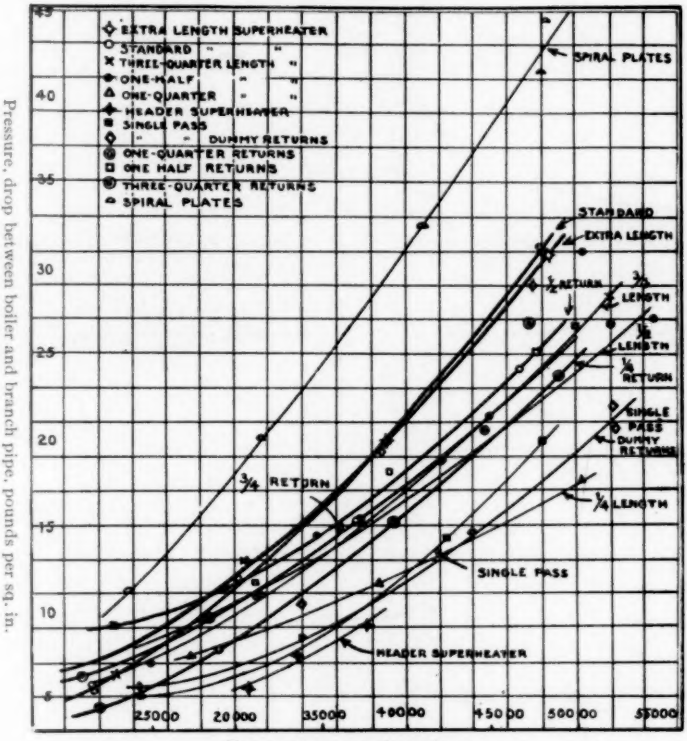
TEMPERATURES IN THE SUPERHEATER FLUE AND THE BOILER TUBE.

Temperatures at a coal burning rate of 5728 pounds. The steam temperature is 651 degrees and is equal to the flue temperature at 170 inches from the firebox.

from the firebox. Figs. 51 and 52 show very similar results in regard to the point where the steam temperature becomes as high as gas temperature. From a consideration of these temperature curves, one reason for the good results by the use of the half-return superheater is made clear.

There is a loss in steam pressure as the steam flows from the boiler through the superheater to the steam chest, and this loss in pressure is shown graphically in Fig. 53. All of the superheaters are shown on this diagram. As would be expected, the superheater having the spiral plates in the tubes shows the

FIG. 53.



LOSS IN STEAM PRESSURE BETWEEN BOILER AND CYLINDERS.

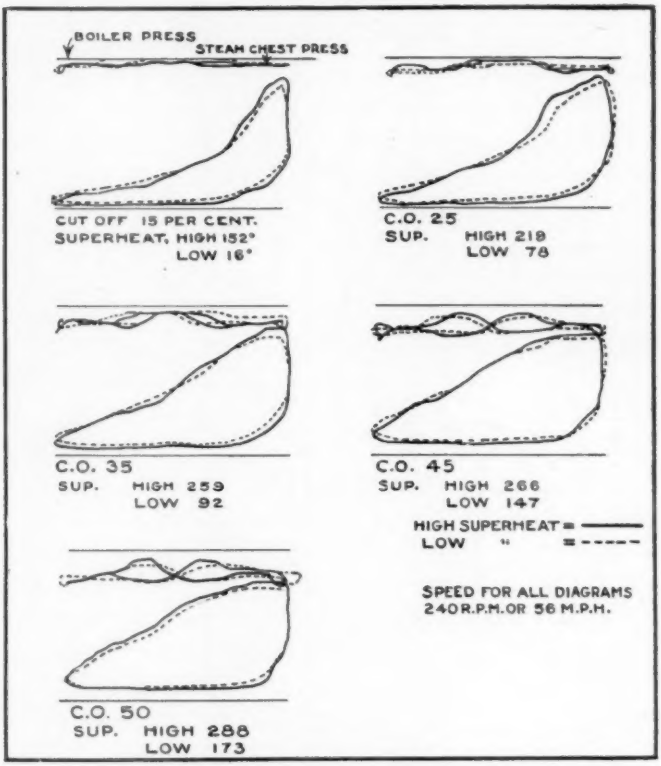
The superheater with spiral plates in the tubes shows the greatest loss in pressure, while the short superheater consisting of short returns at the header shows the least loss.

largest loss in steam pressure as the steam flows through the superheater. These plates have a retarding effect, and, as we have shown in other diagrams, the increase in superheat obtained by their use does not overcome the loss in power due to the pressure drop. The short returns show the least drop in pressure, as is to be expected, the passage through the superheater in this

case being 25 inches in length. The single-pass superheater shows a little greater drop in pressure, it having a length of 497 inches.

Indicator diagrams for high and low superheat are shown in Fig. 54. The first of these diagrams is for a cut-off of 15 per cent. In one case the superheat is 152° and in the other 16°, or

FIG. 54.



INDICATOR DIAGRAMS SHOWING HIGH AND LOW SUPERHEAT.

The greater fluidity of the highly superheated steam is shown by the high initial and low back pressure.

a difference of 136°. There is a drop in pressure between the boiler and steam chest of about 8 pounds. The dotted lines are for steam with a low superheat and the full lines for steam with high superheat. During the admission to the cylinder, the steam having a low superheat shows the lowest pressure during the

whole period of admission. During expansion, however, the pressure for the steam of low superheat is higher than for the highly superheated steam. During the return stroke of the piston, while the steam is flowing out of the cylinder, the steam having a low superheat shows a higher back pressure than the highly superheated steam. The same characteristics are evident on all of the diagrams, and the indications are that the highly superheated steam is more fluid or flows more freely into and out of the cylinder than does the steam of low superheat. It was not possible to make a direct comparison of highly superheated and saturated steam, but there are large differences in the superheat in each pair of diagrams.

The results of the tests show conclusively that there is an almost direct relationship between the economy in water and fuel and the degree of superheat, within the range of the experiments. It would be interesting to know how far this general law holds true for a given economical working cut-off. It is seen that if the superheat, at a short cut-off, could be obtained as high as that which was obtained for a long cut-off, economies more remarkable than are shown, in steam per indicated horse-power hour, would no doubt have been possible. The desirability, therefore, of high-degree superheating for locomotive practice cannot be questioned. Other deductions may be drawn from these tests which, summarized, may be expressed as follows:

(*a*) The standard superheater now in general use is found to give very satisfactory results with a possibility that some of the return portion could be eliminated with no detriment to the superheat obtained, and with an advantage in cost of material.

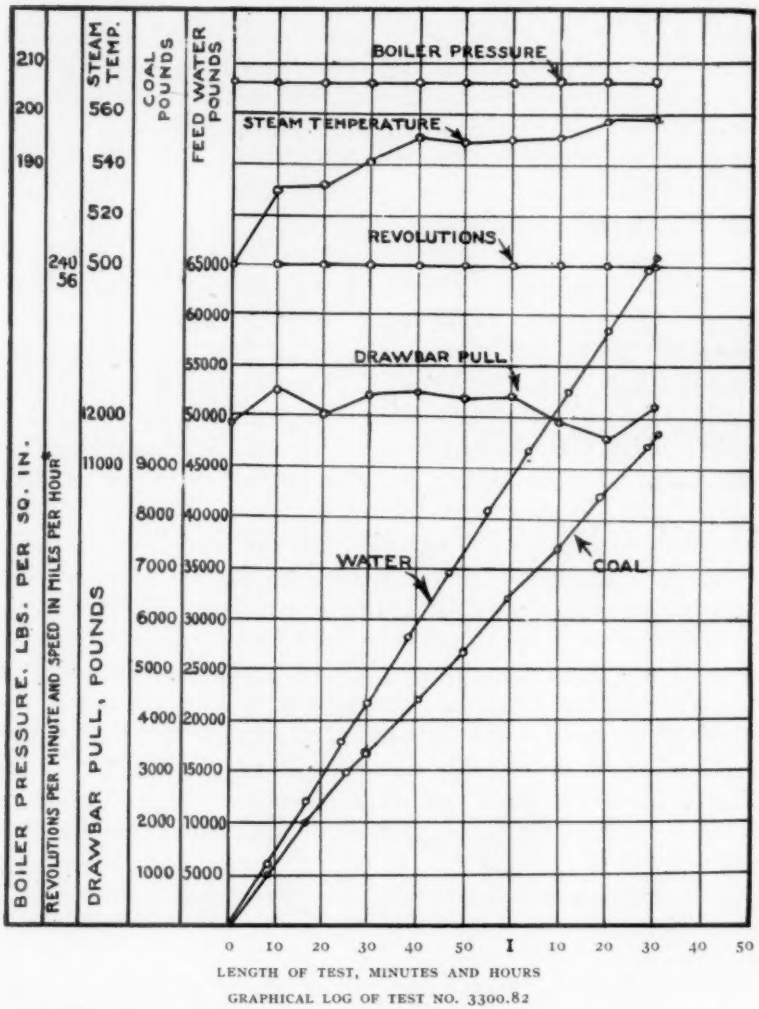
(*b*) Too much importance cannot be attached to the length of superheater; it must extend as far toward the fire as practicable limitations will allow, considering the life of the elements in the hot gases.

(*c*) There is an advantage in the return portion of the superheater, but this part may be shortened; to what extent has not yet been finally determined.

(*d*) As the superheat is reduced, the evaporation of the boiler is increased within certain limits; in other words, a boiler without superheater shows a larger maximum evaporation than one with a superheater. The power of the locomotive, however,

does not increase with the greater weight of steam produced; on the contrary, the power is reduced with the reduction in superheat.

FIG. 55.

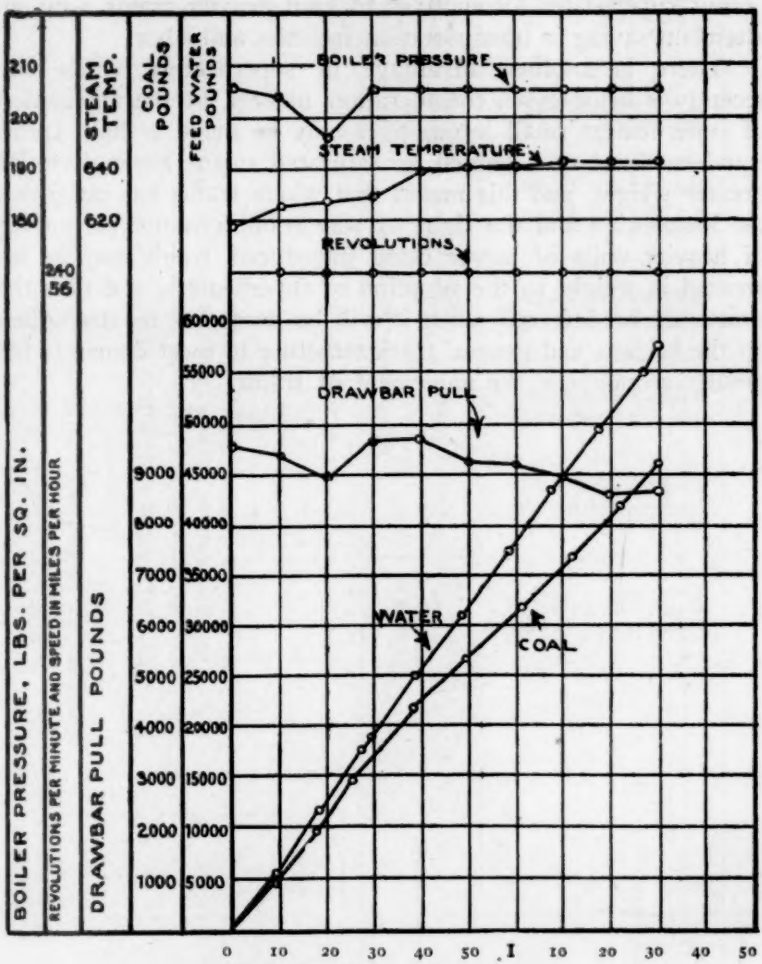


GRAPHICAL LOG OF TEST NO. 3300.82

(*e*) Within the limitations of these tests, the highest superheat does not result in the lowest water rate; this is on account of the fact that to obtain the highest superheat the locomotive

may be run at an excessively long cut-off, the long cut-off increasing the water rate to a greater extent than is compensated for by the increase in superheat.

FIG. 56.



GRAPHICAL LOG OF TEST NO. 3300.91

Applying now the knowledge obtained from these tests to locomotive practice, it is seen that the advantage of superheating may be utilized in two ways: either in coal and water saved, due

to a reduced water rate, or by burning the same amount of coal as would be required in the boiler where it is generating saturated steam and obtaining a decided increase in the power output of the locomotive. If we exclude conditions of starting, this would permit superheater locomotives to haul heavier trains with an attendant saving in transportation facilities and labor.

There is another advantage in superheating which only recently is being given consideration, namely, by the application of superheaters small locomotives may be made to haul trains equal to those now hauled by saturated steam locomotives of greater weight, and this means that where traffic has outgrown the locomotive and the right of way conditions not permitting of heavier units of power being introduced, trains may be increased in weight by the adoption of superheaters, and thus the time may be deferred when it will be necessary to strengthen up the bridges and general track structure to meet demands for greater economy in the movement of trains.

TABLE I.

SUPERHEATER DIMENSIONS AND HEATING SURFACE.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877.)

Superheater.	Length of superheater in flue.	Heating surface, square feet.				Ratio of length of tube to its internal diameter.	Average length of steam passage, inches.	Weights of units, pounds.
		Tubes.	Header.	Return bends.	Total.			
	ft. in.							
Standard	19 0	946.60	16.92	25.80	989.32	848	968	5776
¾ length	14 0½	712.96	16.92	25.80	755.68	643	734	4348
½ length	9 0½	474.21	16.92	25.80	517.13	434	496	3108
¼ length	4 0½	233.56	16.92	25.80	276.28	224	256	1760
Header returns	None	15.56	16.92	16.64	49.12	21	25	442
Extra length	20 5	1016.48	16.92	25.80	1059.20	907	1035	6000
Single pass	18 7¾	491.33	16.92	7.87	516.12	435	497	2952
Single-pass dummy returns	18 7¾	491.33	16.92	7.87	516.12	435	497	5128
¼ returns	19 0	617.04	16.92	25.80	659.76	559	638	3748
½ returns	19 0	719.99	16.92	25.80	762.71	648	740	4492
¾ returns	19 0	837.83	16.92	25.80	880.55	751	857	4888
Spiral plates	14 0½	712.96	16.92	25.80	755.68	643	734	

TABLE II.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.
Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—STANDARD (Altoona, Pa., 10-7-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.87	240-15-F	1.50	56.4	Full	21.6	2115	206.0	3.3	.04	14536	474
3300.88	240-15-F	1.00	56.4	Full	20.7	2100	206.0	3.3	.04	14536	469
3300.89	240-25-F	1.50	56.4	Full	29.8	2347	206.0	6.3	.07	14523	512
3300.90	240-25-F	1.00	56.4	Full	29.7	2350	206.0	5.9	.06	14523	506
3300.91	240-35-F	1.50	56.4	Full	42.9	2480	205.0	10.3	.09	14523	557
3300.92	240-35-F	1.00	56.4	Full	42.2	2480	205.9	10.2	.08	14523	550
3300.93	240-45-F	1.00	56.4	Full	50.7	2627	206.0	14.2	.09	14523	630
3300.94	240-50-F	1.00	56.4	Full	53.3	2690	206.0	15.2	.10	14523	600
3300.95	120-25-F	2.00	28.2	Full	28.1	....	205.1	3.3	.04	14523	481

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.87	2381	44.3	21803	28044	6.5	11.8	812.9	78.6	5.7	200.3	149.0
3300.88	2337	43.5	21492	27711	6.4	11.9	803.2	79.2	5.4	200.6	151.6
3300.89	3609	67.2	29453	38895	9.0	10.8	1127.4	72.0	11.8	194.2	210.3
3300.90	3681	68.5	29237	38753	9.0	10.5	1123.3	70.4	11.3	194.7	218.5
3300.91	6067	112.9	38481	51684	12.0	8.5	1498.1	56.9	19.8	185.2	253.7
3300.92	5738	106.8	38463	51790	12.0	9.0	1501.2	60.3	19.3	186.6	259.2
3300.93	7417	138.1	48224	64861	15.0	8.7	1880.0	58.4	31.0	175.0	265.8
3300.94	7491	139.5	47877	65071	15.1	8.7	1886.1	58.0	31.3	174.7	288.3
3300.95	2210	41.1	20987	26802	6.2	12.1	776.9	81.1	5.3	199.8	124.9

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.87	21428	1362.5	1.8	15.7	0	6251	939.9	2.5	22.8	69.0	6.9	2.2
3300.88	21286	1367.3	1.7	15.6	0.3	6233	937.2	2.5	22.7	68.5	7.0	2.2
3300.89	29326	1841.1	2.0	15.9	28.6	9474	1424.5	2.5	20.6	77.4	6.9	4.0
3300.90	29111	1840.9	2.0	15.8	35.4	9514	1430.5	2.6	20.4	77.7	6.8	4.0
3300.91	37942	2254.3	2.7	16.8	67.2	12129	1823.7	3.3	20.8	80.9	5.3	7.9
3300.92	37850	2278.6	2.5	16.6	72.3	12021	1807.5	3.2	20.9	79.3	5.5	7.6
3300.93	46594	2466.6	3.0	18.9	83.6	13784	2072.6	3.6	22.5	84.0	4.9	13.1
3300.94	47458	2520.3	3.0	18.8	107.5	13493	2028.8	3.7	23.4	80.5	4.8	12.7
3300.95	20877	1145.0	1.9	18.2	0.2	12882	968.5	2.3	21.6	84.6	7.7	1.3

TABLE II A.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal).

SUPERHEATER TESTS—STANDARD (Altoona, Pa., 3-14-1914).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H. P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B. T. U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.130	120-25-F	1.75	28.0	Full	26.3	2343	204.8	2.7	0.07	14504	416
3300.131	240-15-F	1.50	55.9	Full	20.8	2353	206.0	2.9	0.04	14504	429
3300.132	240-15-F	1.00	55.9	Full	20.9	2377	206.0	2.8	0.04	14504	419
3300.133	240-25-F	1.50	55.9	Full	28.1	2460	205.0	5.0	0.08	14504	463
3300.134	240-25-F	1.00	55.9	Full	27.8	2440	204.9	4.9	0.08	14504	451
3300.135	240-35-F	1.50	55.9	Full	39.7	2493	205.9	8.6	0.12	14504	518
3300.136	240-35-F	1.00	55.9	Full	39.7	2500	205.9	8.7	0.13	14504	506
3300.137	240-45-F	0.75	55.9	Full	49.5	2515	205.3	14.0	0.14	14504	568
3300.138	240-50-F	1.00	55.9	Full	53.8	2545	204.6	16.2	0.10	14504	606

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lb.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.130	2295	42.7	20325	26619	6.2	11.6	771.6	77.6	5.8	199.0	151.4
3300.131	2282	42.5	21783	28755	6.7	12.6	833.5	84.3	5.6	200.4	171.5
3300.132	2262	42.1	21630	28623	6.6	12.7	829.7	84.6	5.6	200.4	176.2
3300.133	3257	60.6	28991	38929	9.0	12.0	1128.4	80.0	8.2	196.8	216.1
3300.134	3361	62.6	28903	38857	9.0	11.6	1126.3	77.3	7.8	197.1	217.2
3300.135	4983	92.8	37387	51011	11.8	10.2	1478.6	68.5	15.4	190.5	256.9
3300.136	4897	91.2	37124	50770	11.8	10.4	1471.6	69.4	15.3	190.6	261.8
3300.137	7301	135.9	46720	64415	14.9	8.8	1867.1	59.0	24.1	181.2	274.7
3300.138	8985	167.3	50433	69263	16.0	7.7	2007.6	51.6	31.0	173.6	282.0

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.130	20288	1057.1	2.2	19.2	0	12033	897.4	2.6	22.6	84.9	6.9	1.4
3300.131	21613	1381.3	1.7	15.7	0	6880	1026.2	2.2	21.1	74.3	7.9	3.1
3300.132	21478	1390.7	1.6	15.4	0	6958	1037.9	2.2	20.7	74.6	8.1	2.7
3300.133	28821	1771.0	1.8	16.3	4.1	9542	1423.3	2.3	20.3	80.4	7.7	4.5
3300.134	28757	1775.1	1.9	16.2	5.4	9507	1418.1	2.4	20.3	79.9	7.4	4.3
3300.135	37201	2205.6	2.3	16.9	45.2	13159	1962.8	2.5	19.0	89.0	6.9	7.2
3300.136	36928	2209.4	2.2	16.7	52.3	13254	1977.0	2.5	18.7	89.5	7.1	7.0
3300.137	46244	2464.0	3.0	18.8	72.7	15543	2318.4	3.2	20.0	94.1	5.6	11.2
3300.138	50029	2489.5	3.6	20.1	84.3	15773	2352.7	3.8	21.3	94.5	4.6	13.3

TABLE III.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal).

SUPERHEATER TESTS—THREE-QUARTER RETURN (Altoona, Pa., 3-7-1914).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H. P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B. T. U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.116	120-25-P	2.00	28.0	Full	24.4	2296	205.8	2.8	0.04	14809	442
3300.117	240-15-P	1.50	55.9	Full	17.3	2305	206.0	3.3	0.04	14809	466
3300.118	240-15-P	1.00	55.9	Full	17.6	2320	206.0	3.3	0.04	14809	454
3300.119	240-25-P	1.50	55.9	Full	26.8	2497	205.1	5.6	0.08	14809	509
3300.120	240-25-P	1.00	55.9	Full	27.1	2485	205.0	5.5	0.08	14809	498
3300.121	240-35-P	1.50	55.9	Full	38.8	2583	204.0	9.6	0.12	14603	546
3300.122	240-35-P	1.00	55.9	Full	39.1	2295	204.6	9.6	0.11	14603	541
3300.125	240-45-P	1.00	55.9	Full	48.2	2483	201.3	14.8	0.07	14603	538
3300.126	240-50-P	1.00	55.9	Full	51.9	2323	194.9	15.9	0.07	14603	574

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lb.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.116	2307	42.9	19409	25549	6.1	11.1	740.6	72.5	5.9	199.8	163.3
3300.117	2325	43.3	21161	27836	6.6	12.0	806.8	78.4	6.3	199.7	164.1
3300.118	2297	42.8	20984	27670	6.6	12.1	802.0	79.0	6.3	199.7	168.5
3300.119	3146	58.6	28597	38275	9.1	12.2	1109.4	79.8	9.7	195.4	206.7
3300.120	3260	60.7	28310	37955	9.0	11.6	1101.1	76.3	9.6	195.4	209.8
3300.121	5605	104.3	37534	50801	12.1	9.1	1472.5	60.2	16.0	188.0	240.9
3300.122	5070	94.4	37360	50728	12.1	10.0	1470.2	66.5	15.3	189.3	244.5
3300.125	7626	142.0	44869	61841	14.7	8.1	1792.5	53.9	21.4	179.9	288.2
3300.126	8709	162.1	47203	64785	15.4	7.4	1877.8	49.4	26.8	168.1	280.2

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.116	19279	1044.0	2.2	18.5	7.6	12271	922.5	2.5	20.9	88.4	6.9	1.1
3300.117	21007	1329.1	1.8	15.8	0	6761	1016.6	2.3	20.7	76.5	7.5	3.2
3300.118	20799	1338.2	1.7	15.5	0	6867	1032.5	2.2	20.1	77.2	7.7	2.8
3300.119	28424	1714.9	1.8	16.6	2.9	10329	1540.7	2.0	18.5	89.8	8.4	4.3
3300.120	28170	1723.7	1.9	16.3	2.8	10331	1541.0	2.1	18.3	89.4	8.1	4.1
3300.121	37289	2183.7	2.6	17.1	28.9	12905	1924.9	2.9	19.4	88.2	6.0	8.2
3300.122	37126	2196.4	2.3	16.9	34.5	12911	1925.8	2.6	19.3	87.7	6.6	8.1
3300.125	44636	2411.1	3.2	18.5	85.5	14428	2152.1	3.5	20.7	89.3	4.9	11.8
3300.126	47000	2436.5	3.6	19.3	90.2	15098	2252.0	3.9	20.9	92.4	4.5	13.9

TABLE IV.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—ONE-HALF LENGTH (Altoona, Pa., 8-26-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H. P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B. T. U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle	196	199	203	268 to 271		217	222	225	248	238
3300.23	240-15-P	1.50	56.59	Full	20.3	2260	204.5	3.4	.08	14500	496
3300.24	240-15-P	1.00	56.59	Full	20.8	2245	204.6	3.5	.09	14500	494
3300.25	240-25-P	1.50	56.59	Full	28.3	2273	205.0	6.8	.13	14500	552
3300.26	240-25-P	1.00	56.59	Full	28.7	2270	205.0	6.6	.13	14500	548
3300.27	240-35-P	1.50	56.59	Full	41.9	2360	204.5	12.1	.18	14500	593
3300.28	240-35-P	1.00	56.59	Full	43.2	2360	204.1	12.2	.17	14500	592
3300.29	240-45-P	1.00	56.59	Full	49.3	2400	205.0	17.6	.11	14500	622
3300.30	240-50-P	0.50	56.59	Full	53.2	2580	187.3	17.2	.10	14500	594

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.23	2812	52.4	25156	31302	8.2	11.1	907.3	74.5	7.3	197.2	82.2
3300.24	2780	51.8	25030	31194	8.1	11.2	904.2	75.1	6.9	197.7	84.4
3300.25	4412	82.1	34874	43973	11.5	10.0	1274.6	66.7	14.5	190.5	115.3
3300.26	4427	82.4	34785	43955	11.5	9.9	1274.1	66.5	14.3	190.7	117.8
3300.27	6188	115.2	44801	57111	14.9	9.2	1655.4	61.8	21.0	183.5	146.9
3300.28	6332	117.9	44600	56957	14.8	9.0	1650.9	60.2	20.5	183.6	150.5
3300.29	9031	168.1	54676	69819	18.2	7.7	2023.8	51.7	27.0	178.0	146.9
3300.30	10020	186.5	51932	66232	17.3	6.6	1919.8	44.2	26.8	160.5	149.4

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.23	24877	1362.3	2.1	18.3	0	6478	977.5	2.9	25.5	71.8	6.1	5.7
3300.24	24702	1365.2	2.0	18.1	0	6339	956.6	2.9	25.8	70.1	6.0	5.6
3300.25	34723	1773.4	2.5	19.6	6.6	9619	1451.6	3.0	23.9	81.9	5.8	8.3
3300.26	34635	1772.0	2.5	19.6	6.4	9671	1459.4	3.0	23.7	82.4	5.8	7.5
3300.27	44514	2125.5	2.9	20.9	3.0	12642	1907.8	3.2	23.3	89.8	5.4	11.6
3300.28	44408	2178.9	2.9	20.4	2.8	12637	1907.0	3.3	23.3	87.5	5.3	11.6
3300.29	53883	2402.8	3.8	22.4	8.6	13857	2091.1	4.3	25.8	87.0	4.1	15.8
3300.30	51708	2195.9	4.6	23.6	6.9	13155	1985.2	5.1	26.1	90.4	3.5	15.3

TABLE V.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—ONE-QUARTER LENGTH (Altoona, Pa., 9-8-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B. T. U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle	196	199	203	268 to 271		217	222	225	248	238
3300.39	240-15-F	1.50	56.59	Full	19.6	2220	205.0	4.3	.08	14577	429
3300.40	240-15-F	1.00	56.59	Full	19.4	2200	205.0	4.3	.08	14577	421
3300.41	240-25-F	1.50	56.59	Full	31.0	2290	205.0	8.5	.15	14577	478
3300.42	240-25-F	1.00	56.59	Full	31.1	2295	205.0	8.5	.16	14577	471
3300.43	240-35-F	1.50	56.59	Full	40.9	2343	202.7	14.0	.13	14553	515
3300.44	240-35-F	1.00	56.59	Full	40.6	2360	204.3	14.6	.13	14553	505

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.39	3307	61.6	27013	31662	8.8	9.6	917.8	63.7	7.4	197.6	51.5
3300.40	3189	59.4	27027	33243	9.2	10.4	963.6	69.4	7.3	197.7	53.3
3300.41	4027	91.7	38791	48163	13.4	9.8	1396.0	65.1	11.5	193.5	76.1
3300.42	4922	91.6	38353	47646	13.2	9.7	1381.1	64.4	11.7	193.3	77.6
3300.43	8687	161.7	49953	62335	17.3	7.2	1806.8	47.9	17.6	185.1	88.9
3300.44	8692	161.8	50553	63225	17.3	7.3	1803.6	48.5	17.6	186.7	92.3

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.39	26688	1344.2	2.5	19.9	0	6090	919.0	3.6	29.0	68.4	4.9	4.6
3300.40	26644	1352.9	2.4	19.7	0	5931	895.0	3.6	29.8	66.2	4.9	4.4
3300.41	38516	1765.8	2.8	21.8	2.7	10049	1516.5	3.3	25.4	85.9	5.4	8.4
3300.42	38126	1756.2	2.8	21.7	3.0	10012	1510.9	3.3	25.2	86.0	5.4	8.3
3300.43	49536	2102.9	4.1	23.6	3.9	12365	1866.0	4.7	26.6	88.7	3.8	14.7
3300.44	50088	2118.4	4.1	23.6	5.4	12785	1929.3	4.5	26.0	91.9	3.9	14.2

TABLE VI.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—HEADER RETURNS (Altoona, Pa., 9-20-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.64	240-15-F	1.50	56.6	Full	22.1	2233	204.9	4.9	.08	14163	620
3300.65	240-15-F	1.00	56.6	Full	22.4	2230	205.1	5.0	.08	14163	626
3300.66	240-25-F	0.50	56.6	Full	31.2	2380	177.8	7.0	.10	14163	710
3300.67	240-20-F	0.50	56.6	Full	26.2	2310	190.5	5.6	.09	14163	698
3300.68	120-25-F	2.00	28.3	Full	30.8	2170	205.0	4.1	.07	14163	622

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.64	4509	83.9	30969	37522	11.1	8.3	1087.6	57.0	5.6	199.3	16.6
3300.65	4268	79.5	30820	37345	11.1	8.8	1082.5	60.0	5.5	199.6	15.9
3300.66	5048	94.0	37656	45718	13.6	9.1	1325.2	62.1	9.0	168.8	24.6
3300.67	4152	77.3	33594	40724	12.1	9.8	1180.4	67.2	7.5	183.0	18.9
3300.68	3660	68.1	28400	34445	10.2	9.4	998.4	64.5	5.2	199.8	18.5

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.64	30703	1423.1	3.2	21.6	0	5559	838.9	5.4	36.6	59.0	3.3	7.3
3300.65	30651	1425.2	3.0	21.5	0	5605	845.8	5.1	36.2	59.4	3.6	7.0
3300.66	37493	1547.0	3.3	24.2	0	7249	1093.9	4.6	34.3	70.7	3.9	9.4
3300.67	33449	1476.7	2.8	22.7	1.6	6096	919.9	4.5	36.4	62.3	4.0	7.7
3300.68	28278	1147.9	3.2	24.6	1.8	11725	884.7	4.1	32.0	77.1	4.3	4.4

TABLE VII.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—EXTRA LENGTH (Altoona, Pa., 9-17-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.55	240-15-F	1.50	56.6	Full	21.5	1835	206.0	3.0	.06	14552	411
3300.56	240-15-F	1.00	56.6	Full	21.7	1827	206.0	2.9	.06	14552	413
3300.57	240-25-F	1.50	56.6	Full	30.8	2180	206.0	5.9	.10	14552	545
3300.58	240-25-F	1.00	56.6	Full	30.7	2200	206.0	5.9	.10	14552	546
3300.59	240-35-F	1.50	56.6	Full	42.6	2460	205.6	9.8	.12	14163	592
3300.60	240-35-F	1.00	56.6	Full	42.4	2460	206.0	9.5	.12	14163	595
3300.61	240-45-F	1.00	56.6	Full	51.8	2500	205.4	13.6	.15	14163	603
3300.62	240-50-F	1.00	56.6	Full	52.4	2487	205.0	15.4	.10	14163	604
3300.63	120-25-F	2.00	28.3	Full	29.9	1973	205.8	3.0	.07	14163	449

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.55	2405	44.8	21911	28103	6.4	11.7	814.6	78.0	7.4	198.6	146.1
3300.56	2327	43.3	21489	27673	6.3	11.9	802.1	79.3	6.9	199.1	154.6
3300.57	3450	64.2	30444	40192	9.2	11.7	1165.0	77.7	12.2	193.8	219.0
3300.58	3438	64.0	30115	39893	9.1	11.6	1155.8	77.4	11.9	194.1	226.3
3300.59	5965	111.0	38891	52140	11.9	8.7	1511.3	59.9	20.7	184.9	260.1
3300.60	5458	101.6	38832	52173	11.9	9.6	1512.3	65.5	20.0	186.0	269.7
3300.61	8386	156.1	47478	63960	14.6	7.6	1853.9	52.3	29.7	175.7	278.1
3300.62	7875	146.6	48384	65773	15.0	8.4	1906.5	57.2	30.9	174.1	296.5
3300.63	2461	45.8	20747	26965	6.2	11.0	781.6	75.1	6.8	199.0	172.7

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.55	21732	1433.9	1.7	15.2	0	4976	750.9	3.2	29.0	52.4	5.5	2.3
3300.56	21317	1433.9	1.6	14.9	0	4937	745.0	3.1	28.6	52.0	5.6	2.2
3300.57	30119	1879.9	1.8	16.0	23.4	8745	1319.7	2.6	22.8	70.2	6.7	4.4
3300.58	29906	1892.4	1.8	15.8	30.2	8838	1333.7	2.6	22.4	70.5	6.8	4.0
3300.59	38539	2289.7	2.6	16.8	57.9	11460	1729.4	3.5	22.3	75.5	5.2	8.2
3300.60	38567	2301.0	2.4	16.8	66.4	11313	1707.3	3.2	22.6	74.2	5.6	7.9
3300.61	46106	2482.3	3.4	18.6	89.0	13431	2026.9	4.1	22.8	81.7	4.3	12.9
3300.62	47591	2506.5	3.1	19.0	97.5	13255	2000.3	3.9	23.8	79.8	4.6	13.3
3300.63	20502	1167.6	2.1	17.6	1.4	12290	927.3	2.7	22.1	79.4	6.8	1.6

TABLE VIII.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—SINGLE PASS (Altoona, Pa., 9-27-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle	196	199	203	268 to 271		217	222	225	248	238
3300.69	240-15-F	1.50	56.6	Full	22.5	2023	205.5	3.1	.05	14163	572
3300.70	240-15-F	1.00	56.6	Full	22.5	2035	205.3	3.1	.04	14163	563
3300.71	240-25-F	1.50	56.6	Full	30.6	2336	204.9	6.1	.07	14163	634
3300.72	240-25-F	1.00	56.6	Full	30.8	2347	204.9	6.0	.08	14163	629
3300.73	240-35-F	1.50	56.6	Full	41.1	2403	201.7	10.2	.08	14536	651
3300.74	240-35-F	1.00	56.6	Full	41.4	2405	201.3	10.3	.09	14536	646
3300.75	240-45-F	0.25	56.6	Full	51.9	....	182.3	12.0	.08	14536	647
3300.76	120-25-F	2.00	28.3	Full	31.5	2106	205.1	3.0	.05	14536	551

Test number.	BOILER PERFORMANCE. Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds. Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.	Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	ENGINE PERFORMANCE. Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
	338	339	340	344	345	347	349	350		220	230
3300.69	2542	47.3	24185	30831	8.0	12.1	893.7	83.1	5.4	200.1	119.8
3300.70	2579	48.0	24063	30726	8.0	11.9	890.6	81.6	5.0	200.3	121.6
3300.71	4394	81.8	33951	43894	11.4	10.0	1272.3	68.5	8.7	196.2	151.4
3300.72	4350	81.0	33851	43877	11.4	10.1	1271.8	69.1	8.5	196.4	156.0
3300.73	7245	134.9	42872	55979	14.6	7.7	1622.6	51.6	14.3	187.4	179.6
3300.74	6578	122.5	42336	55473	14.5	8.4	1607.9	56.3	14.2	187.1	187.3
3300.75	8816	164.1	47920	62577	16.3	7.1	1813.8	47.4	20.0	162.3	191.2
3300.76	2597	48.3	22610	28855	7.5	11.1	836.4	74.2	4.9	200.2	118.0

Test number.	ENGINE PERFORMANCE. Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	LOCOMOTIVE PERFORMANCE. Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.69	23884	1382.7	1.8	17.3	0	5197	784.3	3.2	30.5	56.7	5.6	2.8
3300.70	23882	1379.1	1.9	17.3	0	5136	775.0	3.3	30.8	56.2	5.4	2.6
3300.71	33804	1879.9	2.3	18.0	0	8849	1350.5	3.3	25.0	71.9	5.5	4.6
3300.72	33705	1879.9	2.3	17.9	.3	8937	1348.7	3.2	25.0	71.8	5.6	4.1
3300.73	42687	2237.9	3.2	19.1	2.3	11071	1670.7	4.3	25.6	74.7	4.0	8.0
3300.74	42153	2243.0	2.9	18.8	2.7	11101	1675.3	3.9	25.2	74.7	4.5	8.1
3300.75	47686	2273.6	3.9	21.0	23.2	11851	1788.5	4.9	26.7	78.7	3.6	11.6
3300.76	22453	1158.7	2.2	19.4	0	11317	853.9	3.0	26.3	73.7	5.8	1.5

TABLE IX.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—SINGLE PASS, DUMMY RETURNS (Altoona, Pa., 10-1-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle	196	199	203	268 to 271		217	222	225	248	238
3300.77	120-25-F	1.50	28.2	Full	29.1	2210	205.6	3.8	.06	14536	469
3300.78	240-15-F	1.50	56.4	Full	21.3	1960	205.7	3.4	.06	14536	488
3300.79	240-15-F	1.00	56.4	Full	21.2	1960	206.0	3.4	.05	14536	487
3300.80	240-25-F	1.50	56.4	Full	28.4	2331	205.9	7.1	.08	14536	526
3300.81	240-25-F	1.00	56.4	Full	28.5	2335	205.9	6.9	.08	14536	521
3300.82	240-35-F	1.50	56.4	Full	41.6	2410	206.0	12.3	.13	14536	592
3300.83	240-35-F	1.00	56.4	Full	41.4	2415	206.0	12.2	.13	14536	595
3300.84	240-45-F	1.00	56.4	Full	50.6	2450	196.6	14.8	.08	14536	581
3300.85	240-50-F	0.25	56.4	Full	51.5	....	190.3	15.2	.08	14536	600
3300.86	120-25-F	2.00	28.2	Full	29.2	2128	205.8	3.2	.05	14536	449

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.)	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.77	2576	48.0	24192	30264	7.9	11.8	877.2	78.5	6.1	199.5	90.8
3300.78	2871	53.4	24326	30683	8.0	10.7	889.4	71.4	5.7	200.0	95.7
3300.79	2596	48.3	24192	30553	8.0	11.8	885.6	78.6	5.6	200.4	97.1
3300.80	3710	69.1	33940	43378	11.3	11.7	1257.3	78.0	10.6	195.3	127.8
3300.81	3747	69.8	33789	43310	11.3	11.6	1255.4	77.2	10.5	195.4	132.8
3300.82	6271	116.7	44166	57090	14.9	9.1	1654.8	60.8	14.5	191.5	157.3
3300.83	6095	113.5	43857	56947	14.8	9.3	1650.6	62.4	14.6	192.0	166.7
3300.84	9044	168.4	52299	67717	17.6	7.5	1962.8	50.0	20.7	175.9	169.0
3300.85	9180	170.9	52032	67231	17.5	7.3	1948.7	48.9	22.0	168.3	165.8
3300.86	2312	43.0	22720	28766	7.5	12.4	833.8	83.1	5.1	200.7	104.7

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust. super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.77	24058	1146.4	2.3	21.0	0	12725	956.7	2.7	25.2	83.5	6.5	2.6
3300.78	24044	1308.4	2.2	18.4	0	6023	905.6	3.2	26.6	69.2	5.5	3.0
3300.79	23918	1313.6	2.0	18.2	0	5938	892.8	2.9	26.8	68.0	6.0	3.0
3300.80	33519	1732.9	2.1	19.3	0.7	9102	1368.2	2.7	24.5	79.0	6.5	6.1
3300.81	33546	1773.8	2.1	18.9	0.3	9165	1378.0	2.7	24.3	77.7	6.4	6.3
3300.82	43911	2212.4	2.8	19.9	2.3	12076	1815.7	3.5	24.2	82.1	5.1	11.0
3300.83	43637	2229.6	2.7	19.6	2.9	12098	1819.1	3.4	24.0	81.6	5.2	10.7
3300.84	51924	2474.7	3.7	21.0	7.8	13361	2009.0	4.5	25.9	81.2	3.9	14.1
3300.85	51808	2369.7	3.9	21.9	14.3	13047	1961.7	4.7	26.4	82.8	3.7	14.9
3300.86	22328	1126.1	2.1	19.8	0	12407	932.8	2.5	23.9	82.8	7.1	2.0

TABLE X.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—ONE-QUARTER RETURNS (Altoona, Pa., 10-15-1913).

Test. number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.99	240-15-F	1.50	56.4	Full	20.7	2257	205.9	2.9	.04	14523	474
3300.100	240-15-F	1.00	56.4	Full	20.5	2235	205.9	2.9	.04	14523	470
3300.101	240-25-F	1.50	56.4	Full	30.1	2395	205.4	5.9	.08	14487	539
3300.102	240-25-F	1.00	56.4	Full	29.6	2410	205.6	5.7	.08	14487	540
3300.103	240-35-F	1.00	56.4	Full	41.1	2365	206.0	10.2	.08	14487	529
3300.104	240-35-F	0.50	56.4	Full	41.2	2350	206.0	10.0	.08	14487	565
3300.105	240-45-F	1.00	56.4	Full	52.6	2515	203.4	14.2	.07	14487	605
3300.106	120-25-F	2.00	28.2	Full	30.1	2162	206.0	3.1	.05	14487	474

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.99	2362	44.0	22123	28277	7.1	12.0	819.6	80.0	4.4	201.5	135.6
3300.100	2412	44.9	22008	28211	7.1	11.7	817.7	78.2	4.3	201.6	138.3
3300.101	3924	73.0	31342	40635	10.2	10.4	1177.8	69.4	11.0	194.4	170.2
3300.102	3690	68.7	31259	40752	10.2	11.0	1181.2	74.0	10.9	194.7	177.8
3300.103	5771	107.4	40419	53852	13.5	9.3	1560.9	62.5	15.9	190.1	230.3
3300.104	5884	109.5	39330	52527	13.2	8.9	1522.5	59.8	15.2	190.8	235 5
3300.105	9635	179.4	48908	65323	16.4	6.8	1893.4	45.5	23.7	179.7	239.6
3300.106	2542	47.3	21527	27592	6.9	10.9	799.8	72.7	4.5	201.5	131.5

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust super-heat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.99	21837	1366.0	1.7	16.0	0	6397	961.9	2.5	22.7	70.4	7.1	0.4
3300.100	21729	1368.2	1.8	15.9	0	6240	938.2	2.6	23.2	68.6	6.8	0.9
3300.101	31088	1787.0	2.2	17.4	3.7	9904	1489.2	2.6	20.9	83.3	6.7	3.1
3300.102	30968	1789.6	2.1	17.3	3.7	9791	1472.2	2.5	21.0	82.3	7.0	2.4
3300.103	39452	2276.9	2.5	17.3	51.3	12735	1914.8	3.0	20.6	84.1	5.8	6.1
3300.104	39079	2277.5	2.6	17.2	55.8	12735	1914.8	3.1	20.4	84.1	5.7	5.5
3300.105	48168	2489.3	3.9	19.4	72.7	13410	2016.3	4.8	23.9	81.0	3.7	10.6
3300.106	21429	1141.7	2.2	18.8	2.4	12988	976.4	2.6	22.0	85.5	6.8	1.5

TABLE XI.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.
Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—ONE-HALF RETURNS (Altoona, Pa., 9-12-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box. temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.46	240-15-F	1.50	56.6	Full	20.7	2023	206.0	3.4	.06	14553	419
3300.47	240-15-F	1.00	56.6	Full	23.2	2005	206.0	3.4	.06	14553	415
3300.48	240-25-F	1.50	56.6	Full	28.8	2298	205.5	6.3	.09	14553	448
3300.49	240-25-F	1.00	56.6	Full	29.7	2298	205.7	6.2	.09	14553	433
3300.50	240-35-F	1.50	56.6	Full	42.3	2376	205.6	11.2	.16	14553	512
3300.51	240-35-F	1.00	56.6	Full	42.6	2382	205.6	11.2	.17	14553	504
3300.52	240-45-F	1.00	56.6	Full	50.4	2465	205.3	15.9	.14	14553	531
3300.53	240-50-F	1.00	56.6	Full	54.0	2585	205.0	16.2	.13	14553	568
3300.54	120-20-F	2.00	28.3	Full	28.9	1798	205.3	3.5	.07	14553	...

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.46	2773	51.6	22787	29134	7.1	10.5	884.5	70.1	9.4	196.6	146.7
3300.47	2687	50.0	22766	29207	7.2	10.9	846.6	72.5	9.1	196.9	152.9
3300.48	3858	71.8	31130	40629	9.9	10.5	1177.7	70.2	12.0	193.5	214.4
3300.49	3822	71.2	31123	41044	10.1	10.7	1189.6	71.6	11.7	194.0	221.6
3300.50	5298	98.6	39322	52794	12.9	10.0	1530.3	65.3	17.9	187.7	272.4
3300.51	5278	98.3	39003	52481	12.9	9.9	1521.2	66.3	18.0	187.6	278.8
3300.52	7494	139.5	47612	64497	15.8	8.6	1869.5	57.4	25.2	180.1	297.5
3300.53	7480	139.2	49905	66724	16.3	8.9	1934.0	59.5	26.7	178.3	263.6
3300.54	2457	45.7	20938	26921	6.6	11.0	780.3	73.1	5.5	199.8	159.4

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.46	22614	1437.2	1.9	15.7	0	6854	1034.3	2.7	21.9	72.0	6.5	2.4
3300.47	22556	1449.9	1.9	15.6	0	6874	1037.3	2.6	21.8	71.6	6.8	2.3
3300.48	30927	1926.7	2.0	16.1	13.2	11067	1670.1	2.3	18.5	86.7	7.6	4.8
3300.49	30887	1926.1	2.0	16.0	17.4	11180	1687.1	2.3	18.3	87.6	7.7	4.5
3300.50	39076	2342.3	2.3	16.7	62.2	13289	2005.4	2.6	19.5	85.6	6.6	8.0
3300.51	38835	2355.3	2.2	16.5	69.6	13219	1994.9	2.7	19.5	84.7	6.6	7.9
3300.52	47093	2592.3	2.9	18.2	98.5	14713	2220.3	3.4	21.2	85.7	5.2	12.9
3300.53	49379	2597.6	2.9	19.0	81.4	13828	2086.8	3.6	23.7	80.3	4.9	15.1
3300.54	20789	1162.6	2.1	17.9	0	11793	889.8	2.8	23.4	76.5	6.3	2.6

TABLE XII.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—THREE-QUARTERS RETURNS (Altoona, Pa., 10-22-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire box temp.	Pressure in boiler, lbs. per sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.107	120-25-F	2.00	28.2	Full	28.6	2014	206.0	3.1	.05	14487	494
3300.108	240-15-F	1.50	56.4	Full	21.0	2117	206.0	2.7	.06	14487	510
3300.109	240-15-F	1.00	56.4	Full	20.6	2070	206.0	2.7	.05	14487	509
3300.110	240-25-F	1.50	56.4	Full	31.1	2327	205.8	5.5	.07	14487	562
3300.111	240-25-F	1.00	56.4	Full	30.9	2335	205.7	5.5	.07	14487	561
3300.112	240-35-F	1.50	56.4	Full	42.2	2430	206.0	9.8	.10	14487	594
3300.113	240-35-F	1.00	56.4	Full	42.0	2440	206.0	9.5	.10	14487	582
3300.114	240-45-F	1.00	56.4	Full	52.7	2490	205.3	13.8	.08	14487	621
3300.115	240-50-F	1.00	56.4	Full	53.7	2590	204.6	13.8	.06	14121	614

Test number.	BOILER PERFORMANCE.									ENGINE PERFORMANCE.	
	Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds.			Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
				Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.					
	338	339	340	344	345	347	349	350		220	230
3300.107	2221	41.3	21353	27395	6.5	12.3	794.1	82.6	7.0	199.0	134.2
3300.108	2600	48.4	22201	28424	6.8	10.9	823.9	73.2	6.9	199.1	129.6
3300.109	2374	44.2	22005	28260	6.7	11.9	819.1	79.7	6.6	199.4	134.1
3300.110	3719	69.2	30442	39841	9.5	10.7	1154.8	71.7	14.6	191.2	179.3
3300.111	3616	67.3	30424	39890	9.5	11.0	1156.2	73.9	14.3	191.4	186.3
3300.112	5160	96.1	39674	52800	12.6	10.2	1530.4	68.5	25.0	181.0	226.6
3300.113	5215	97.1	39192	52299	12.4	10.0	1515.9	67.2	24.0	182.0	232.1
3300.114	7653	142.5	47490	63571	15.1	8.3	1842.4	55.7	33.6	171.7	245.2
3300.115	10793	200.9	47931	64438	15.3	6.0	1867.8	41.0	29.5	175.1	253.0

Test number.	ENGINE PERFORMANCE.					LOCOMOTIVE PERFORMANCE.						
	Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent. (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.107	21261	1130.5	2.0	18.8	2.4	12958	974.2	2.3	21.8	86.2	7.7	1.9
3300.108	21969	1357.1	1.9	16.2	5.5	6690	1005.9	2.6	21.8	74.1	6.8	2.2
3300.109	21783	1360.3	1.8	16.0	5.4	6402	962.6	2.5	22.6	70.8	7.1	2.3
3300.110	30311	1823.0	2.0	16.6	10.7	9999	1503.4	2.5	20.2	82.5	7.1	4.5
3300.111	30293	1825.9	2.0	16.6	11.8	9806	1474.4	2.5	20.6	80.8	7.2	4.4
3300.112	39166	2264.9	2.3	17.3	54.4	13259	1993.6	2.6	19.7	88.0	6.8	8.3
3300.113	38721	2270.0	2.3	17.1	59.2	13009	1956.0	2.7	19.8	86.2	6.6	8.1
3300.114	46777	2467.1	3.1	19.0	79.2	13677	2056.5	3.7	22.8	83.4	4.7	11.5
3300.115	47636	2463.7	4.4	19.3	89.5	13934	2095.1	5.2	22.7	85.0	3.5	12.6

TABLE XIII.

AVERAGE RESULTS OF LOCOMOTIVE TESTS.

PENNSYLVANIA RAILROAD COMPANY.

Philadelphia, Baltimore & Washington Railroad Company.
Northern Central Railway Company.
West Jersey & Seashore Railroad Company.

TEST DEPARTMENT.

(Locomotive: Type 4-6-2; Class K2sa; No. 877; Fuel, Penn Gas Coal.)

SUPERHEATER TESTS—SPIRAL PLATES (Altoona, Pa., 9-2-1913).

Test number.	RUNNING CONDITIONS.						BOILER PERFORMANCE.				
	Test designation.	Duration of test, hours.	Miles per hour.	Throttle opening, full or partial.	Actual cut-off per cent., H.P. cylinders.	Fire-box temp.	Pressure in boiler, lbs. per. sq. inch.	Draft in smokebox, inches of water.	Draft in ash pan, inches of water.	Calorific value of dry fuel, B.T.U. per lb.	Smoke-box temp.
	R. P. M. cut-off throttle.	196	199	203	268 to 271		217	222	225	248	238
3300.31	240-15-F	1.50	56.59	Full	19.2	2277	205.9	3.6	.07	14577	448
3300.32	240-15-F	1.00	56.59	Full	19.6	2285	205.9	3.6	.07	14577	447
3300.33	240-25-F	1.25	56.59	Full	28.6	2323	204.8	6.5	.10	14577	513
3300.34	240-25-F	0.75	56.59	Full	28.8	2330	204.8	6.5	.10	14577	507
3300.35	240-35-F	1.50	56.59	Full	41.1	2400	206.0	10.6	.12	14577	544
3300.36	240-35-F	1.00	56.59	Full	41.3	2405	206.0	10.4	.12	14577	543
3300.37	240-45-F	1.00	56.59	Full	50.2	2470	204.9	15.2	.14	14577	540
3300.38	240-50-F	1.00	56.59	Full	52.3	2490	205.6	14.9	.14	14577	543

Test number.	BOILER PERFORMANCE. Dry fuel fired per hour, pounds.	Dry fuel per hour, pounds per sq. ft. of grate.	Water delivered to boiler, pounds per hour.	Equivalent evaporation from and at 212° F., pounds. Per hour.	Per hour per sq. ft. of fire heating sur.	Per pound of dry fuel.	Boiler horse-power (34½ U. of E.).	Efficiency of boiler, based on fuel.	Pressure loss, lbs.	ENGINE PERFORMANCE. Pressure in branch pipe, pounds per sq. in.	Superheat in branch pipe, degrees F.
	338	339	340	344	345	347	349	350		220	230
3300.31	2765	51.5	23627	29665	7.3	10.7	859.9	71.4	11.4	194.5	104.1
3300.32	2843	52.9	23745	29857	7.3	10.5	865.4	69.9	11.2	194.7	106.5
3300.33	3838	71.5	31949	40893	10.0	10.7	1185.3	70.9	20.4	184.4	151.7
3300.34	3772	70.2	31584	40499	9.9	10.7	1173.9	71.5	20.2	184.6	155.1
3300.35	5366	99.9	40939	52888	13.0	9.9	1532.8	65.6	32.8	173.2	177.1
3300.36	5340	99.4	41005	53102	13.0	9.9	1539.2	66.2	32.6	173.4	182.0
3300.37	6891	128.3	48058	62311	15.3	9.0	1806.1	60.2	41.5	163.4	191.4
3300.38	7110	132.4	48384	62945	15.4	8.9	1824.5	58.9	44.5	161.1	197.3

(*To be continued.*)

Test number.	ENGINE PERFORMANCE. Dry steam to engines, pounds per hour.	Indicated horse-power.	Dry fuel per indicated horse-power hour, pounds.	Dry steam per indicated horse-power hour, pounds.	Exhaust superheat.	LOCOMOTIVE PERFORMANCE. Drawbar pull, pounds.	Dynamometer or drawbar horse-power.	Dry fuel per dynamom. horse-power hour, pounds.	Dry steam per dynamom. horse-power hour, pounds.	Machine efficiency of locomotive, per cent.	Thermal efficiency of locomotive, per cent (based on fuel).	Least back press.
	214	379	380	381		265	383	384	385	398	399	
3300.31	23499	1376.9	2.0	17.1	1.7	6340	956.7	2.9	24.6	69.5	6.0	4.1
3300.32	23604	1378.1	2.1	17.1	1.8	6192	934.4	3.0	25.3	67.8	5.7	4.1
3300.33	31709	1775.6	2.2	17.9	1.8	9513	1435.6	2.7	22.1	80.9	6.5	6.3
3300.34	31360	1778.0	2.1	17.6	1.4	9437	1424.1	2.7	22.0	80.1	6.6	6.0
3300.35	40762	2088.2	2.6	19.5	2.6	12080	1822.9	2.9	22.4	87.3	5.9	8.3
3300.36	40829	2098.5	2.5	19.5	3.3	12112	1827.8	2.9	22.3	79.5	6.0	7.9
3300.37	47396	2200.6	3.1	21.5	22.4	12967	1956.8	3.5	24.2	88.9	5.0	11.9
3300.38	48014	2208.3	3.2	21.7	31.1	13607	2053.4	3.5	23.4	93.0	5.1	11.9

Rail Steels for Electric Railways. W. WILLCOX. (*Times, Eng. Suppl.*, Feb. 25, 1914.)—This gives the results of some tests made to determine the most suitable rail to withstand the heavy wear of electric railway rolling stock. For the last seven years high-silicon steel has been used and has proved more durable and considerably less liable to rust than ordinary steel. It is made from basic open-hearth, basic Bessemer, or acid Bessemer steels by the Sandberg process, in which during the manufacture the whole of the silicon is extracted and a known quantity added. The rails are 45 feet long and weigh 86 lbs. per yard. The results as regards life were: High-silicon basic open-hearth, over 23 months; high-silicon acid Bessemer, first lot of rails on the down road, 11 months, second lot of rails just over 15 months, and on the up road, just over 15 months; basic open-hearth titanium, 9⅓ months; and ordinary basic open-hearth 9⅓ months on the down road, and barely 11 months average on the up road. Silicon steel is especially suitable in tunnels, on account of its comparative freedom from rusting as compared with ordinary steel; moreover the price is not more than 10 per cent. per ton in excess of the price of ordinary steel, whereas nickel steel, chrome steel, etc., cost much more. A test was made of rolled manganese-steel rails, containing C, 1.20; SiO_2, 0.30; S, 0.03; P, 0.06; and Mn, 12.00 per cent. Two pairs of 95-lb. rolled manganese rails of British standard section were placed near Moorgate Street on a 15 chain curve. After being there nine months, they were put on the curve between Farringdon Street and Aldersgate Street, on the down road just outside the tunnel. The original weights when put in the road near Moorgate Street were No. 1 high rail, 1425 lbs.; No. 1 low rail, 1427 lbs.; No. 2 high rail, 1428 lbs.; and No. 2 low rail 1400 lbs. When put in the curve at Farringdon Street on January 6, 1912, No. 1 high rail had lost 22 lbs. in weight, No. 1 low rail 17 lbs., No. 2 high rail 14 lbs. and No. 2 low rail 17 lbs. This gives an average loss of 1.56 lbs. per yard per annum. Weighed again on Oct. 11, 1913, the weights were No. 1 high rail 1333 lbs.; No. 1 low rail, 1393; No. 2 high rail, 1375 lbs., and No. 2 low rail 1365 lbs. The total loss in weight: No. 1 high rail, 92 lbs.; No. 1 low rail, 34 lbs.; No. 2 high rail, 53 lbs., and No. 2 low rail, 35 lbs., equal to an average of 1.43 lbs. per yard per annum. After a period of two years and six months these rails, although wearing away, are wearing evenly, and show no signs of battering, as even the hardest of the other rails tested did.

RESISTIVITY OF PURE SILVER; SOLID AND MOLTEN.*

BY

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Member of the Institute.

THE silver used in the measurements here recorded was very pure. It was given to the writer by Prof. G. A. Hulett from the supply which he is using in connection with his study of the silver voltameter. The writer takes this opportunity of expressing his very great indebtedness to Professor Hulett not only for supplying the silver for the measurements recorded here, but also for numerous courtesies and encouragements rendered the writer in connection with his general research.

The resistivity of the silver in the form of a soft drawn wire was determined between 20° C. and 60° C., using an oil-bath, mercury thermometer, and Kelvin double bridge. The same silver was then used in a container and measured as the temperature was slowly decreased and increased between 1340° C. and 20° C.

The manner of making the measurement and the apparatus used were the same as have already been described by the writer in this JOURNAL, in the articles, "Resistivity of Copper in Temperature Range 20° C. to 1450° C." (January, 1914), and "Resistivity of Pure Gold in Temperature Range 20° C. to 1500° C." (March, 1914).

While it has been the writer's custom to repeat the determination using a different container in each case and thereby check the precision of his results, this was not done in the case of silver because of press of other investigations and because his increased familiarity with the method employed makes it entirely unlikely that any gross error has intruded.

The results obtained are fully set forth in Curves I, II, and III, and in the table at the end of the article.

Curve I is a plot of the resistivity of silver in the form of a soft drawn wire in the range 20° to 60° C.

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* Communicated by the Author.

Curve II is a plot of the resistivity in the range 20° C. to 1340° C. obtained in measuring the same silver in a container of magnesite 40 parts and alundum 60 parts.

As has been explained in the articles referred to above, the portion of the curve which gives the resistivity in the solid state will be a little too high in the case of those metals which contract upon solidification, as is the case with silver.

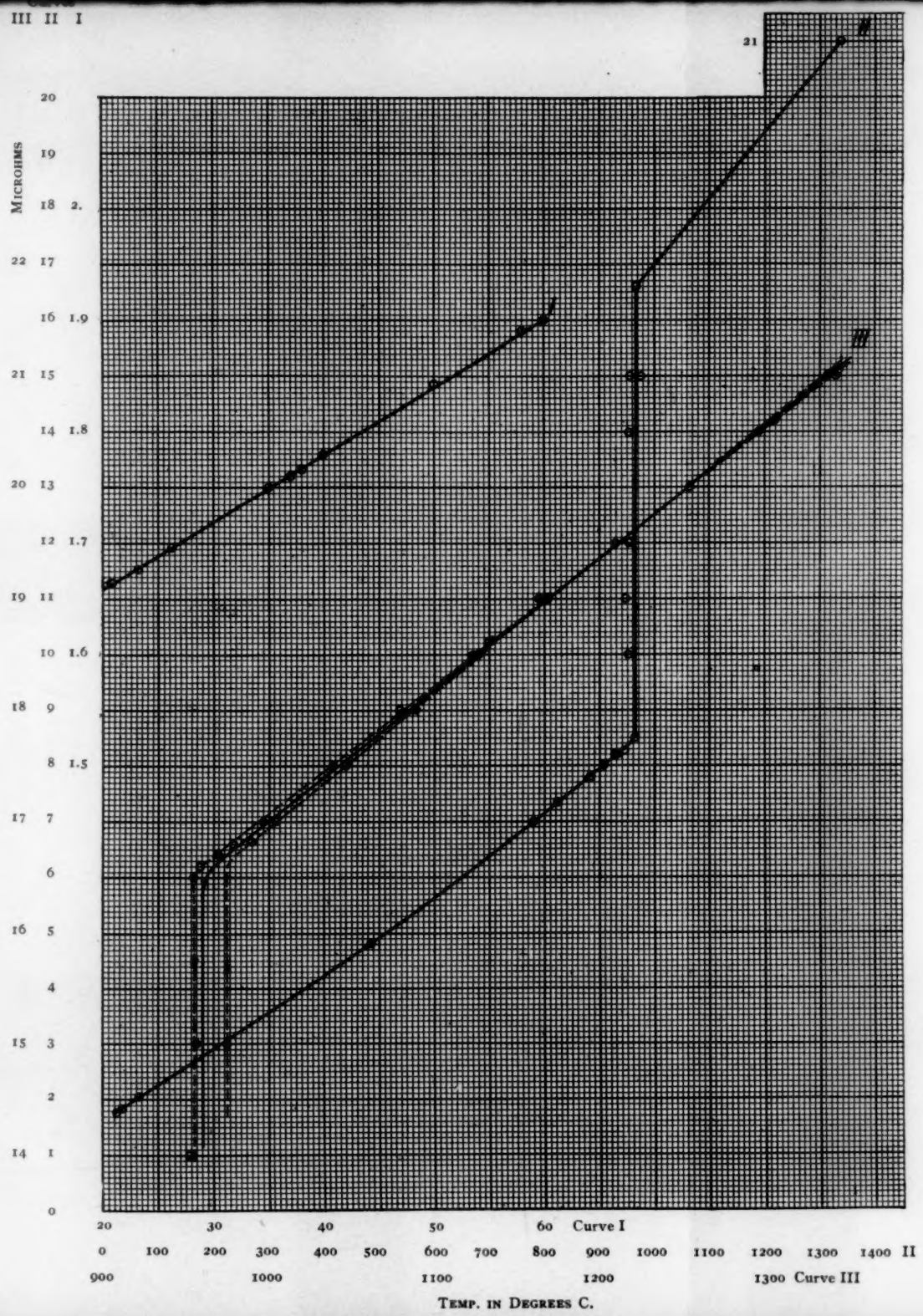
Curve III is a plot upon a larger scale than Curve II of the data obtained for molten silver.

Curve I shows that in the range 20° C. to 60° C. the increase in resistivity with temperature is linear within the limits of accuracy of the measurement. It appears, however, from Curve II that over the wide range 20° C. to 960° C. the resistivity of silver in the solid state gives a curve which is slightly convex toward the temperature axis. The curve is, in this respect, the same as for gold and copper. At the moment of fusion the resistivity suddenly increases (which is the characteristic of all metals examined except bismuth and antimony, which contract on liquefying) from 8.5 to 16.6 microhms.

The resistivity as shown by Curve II before fusion is, however, slightly too great on account of shrinkage in solidifying. Since the resistivity of the wire at 20° C. is 1.65_9, while the value obtained for silver which has cooled in the container is 1.74_9, it is thought that we should call the resistivity just before fusion 8.4. This would make the ratio of the resistivity just after fusion to the resistivity just before fusion 1.98.

The points shown on the curves are those actually obtained. A few points which were in error, for obvious reasons have been omitted. It will be noted in Curve III that the slant of the two dotted lines which give the values obtained with rising and with falling temperature is not quite the same. The cause of this is not known with certainty, but it is supposed to be due to a lag of the temperature of the molten metal behind the temperature of the platinum *vs.* platinum + 10 per cent. rhodium thermocouple used. The heavy line has been drawn as a mean. The departure from the mean at 960° C. is about 0.6 per cent., which may be taken as the probable error in the measurements of the resistivity in the molten state.

The measurement was not carried higher than 1340° C. be-


III II I
MICROHMS
TEMP. IN DEGREES C.
Curve I
II
Curve III

cause the thermocouple failed at this temperature, due to the opening of its circuit.

Within the limits of the precision of the measurement, the resistivity of silver in the molten state increases linearly from its melting temperature to the highest temperature measured, 1340° C.

This property which many of the metals have of apparently increasing linearly in their molten state to the highest temperatures at which they have so far been studied has great interest. The writer is now engaged in examining several of the metals in pairs simultaneously to determine if a molten metal, as tin, which melts at a low temperature and boils at a high temperature, may be used to establish the temperature scale far beyond the limits of the gas thermometer. He has so far worked up to 1680° C., using tin and copper, with remarkably concordant results—but this is a matter for a later report.

The following table summarizes the values which have interest relating to pure silver:

Degrees Centigrade	Microhms per centimetre	Ratios, ρ_t/ρ_{t_1}	Remarks
20	1.65$_9$	.....	
60	1.90$_0$	.....	Increase per 100° C.=0.60 microhms.
960.5	8.4	.....	Silver solid.
960.5	16.6	ρ_m/ρ_s=1.98	Silver molten.
1000	17.01	.....	Temperature coefficient calculated from 1000° C.=0.00069.
1100	18.19		
1200	19.36		
1300	20.54	.....	Increase per 100° C.=1.177 microhms.
1340	21.01		

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Temiskamite, a New Nickel Arsenide. T. L. WALKER. (*Amer. J. Sci.*, xxxvii, 170.)—Temiskamite has a composition corresponding to Ni_4As_3. The mineral occurs in calcite veins carrying nicolite and smaller amounts of native bismuth and silver. It is silver-white, with a touch of red, tarnishing very quickly to madder gray. Hardness, 5.5; specific gravity, 7.901; fusibility, 2; lustre, metallic.

The Haze of 1912. ANON. (*Sci Amer.*, cx, No. 6, 112.)—The remarkable turbidity of the atmosphere in the summer and autumn of 1912, with its attendant optical phenomena, has generally been attributed to the presence of dust from the eruption of Mount Katmai, Alaska. However, the question as to the cause of this haze has recently been reopened by Dr. Barkow, who, as a member of Filchner's Antarctic expedition, observed similar phenomena in latitude 70° south, as early as the middle of June 1912, and during some months afterwards. Cirrus clouds of unusual altitude were noted, and the illumination of the northern sky at midday (with the sun below the horizon) was so bright that it was possible to read for several hours. In other words, the phenomena strongly indicated the presence of some light-reflecting substance at an abnormal height in the atmosphere. As it is not thought possible that dust from Katmai could have travelled to the Antarctic so soon after the eruption, Dr. Barkow suggests that the dust was of cosmical origin, though its effects were probably heightened in the northern hemisphere by volcanic dust.

The Kilowatt as the Unit of Power in the Metric System. G. DARRIEUS. (*Lumière Electr.*, xxiv, 336.)—The many advantages are pointed out that accrue from adopting the kilogramme as the standard of mass, and the metre as the unit of length. The unit of force, for example, would be the force that would have to be applied to the mass of 1 kg. in order to give it an acceleration of 1 metre per second. It would, therefore, equal 10^5 dynes. It is suggested that this unit be called the *cop*, from Copernicus. The unit of work in this system would be $10^5 \times 10^2$, *i.e.*, 10^7 ergs or the joule. The unit of power would be the watt. Examples are given to show how engineering calculations would be simplified by adopting the metre-kilogramme-second system.

AN APPARATUS FOR THE SPECTROSCOPIC SYNTHESIS OF COLOR.*

BY

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AND

E. J. BRADY,
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In the study of the problems of color mixture, and in the practical problem of producing artificial light of a desired color, such as that of daylight, it frequently becomes desirable to have some means of producing at will a light which shall possess identically a chosen energy distribution. For this purpose something more exact than colored absorbing media is desired, for these only by rare chance possess, wave-length by wave-length, the transmission necessary. Even when combinations of these are capable of producing the desired absorption, the task of measuring and combining the various constituent elements is practically prohibitive as a general color-producing proposition. A means is called for which shall make possible and easy the production, for instance, not only of energy distributions derived from spectrophotometric measurements, but also those calculated from formulæ such as the Wien-Planck equation for black bodies at various terrestrially unattainable temperatures.

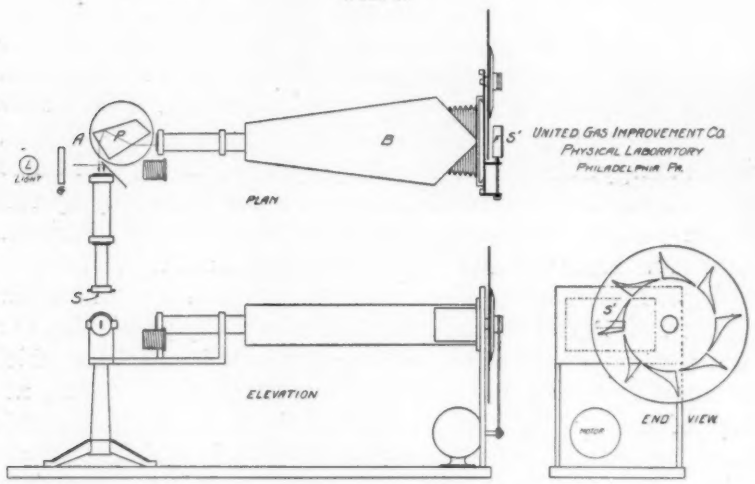
The apparatus here described is similar in principle to one described by Abney in his "Color Measurement and Mixture." It consists of a spectroscope fitted with a revolving disc pierced with openings which act as templates for altering the relative intensities of the various constituent colors of the spectrum of the illuminant used with it. The present instrument is distinctive in employing the principle utilized in Maxwell's color box; that is, the use of an extended area for the source of light, and in being designed as an attachment for a standard laboratory instrument—the Hilger constant deviation spectrometer with photographic

* Communicated by Dr. Ives.

attachment. The principle of the device is best explained by reference to Fig. 1, representing the spectrometer and its attachment.

A is the constant deviation spectrometer and *B* the camera attachment. As ordinarily used, the light source is placed at the slit *S*, and an extended spectrum is formed at S^1. If a convex lens is placed at S^1, of properly chosen focal length, this spectrum may be recombined and an image of the prism face formed of the same color as the light entering the slit *S*. If, in addition, at S^1 is placed a neutral tint absorbing screen of different transmission at different points along S^1, the color of the recombined

FIG. 1.



light can be altered. The most definite and satisfactory way to thus alter the spectrum is by means of a rapidly rotating sector whose openings are of such shape that the various parts of the spectrum are reduced to exactly a desired proportion.

A disadvantage of the apparatus as just described lies in the small amount of light available after this projection and recombination and in the use of more parts than are necessary to achieve the result. A very satisfactory way to use a spectrometer for color work where an extended surface is desirable is to observe the prism face through an eye-slit. This may be done with the present apparatus by simply reversing it. If the opening S^1 be uniformly illuminated by the light source (as

by illuminating the white surface F), then the eye placed at S sees the prism face of the color of the light used. Now, each element of the opening S^1 is virtually a slit forming a spectrum at S; it is the overlapping of these spectra that gives the integral color. If any of these elements is utilized alone, the prism face is observed of the color that element would receive were the light source at S. In short, the rotating sector or template will affect the color of the prism face in this arrangement just as it would affect the color of the recombined spectrum image before considered. It is only necessary in this case to have an extended uniformly bright source at S^1, which is easily provided.

With the apparatus as arranged, the next step is to calculate the openings of the sectors. This is done by a series of straightforward steps. First must be known the relative energy distribution of the source available for illuminating F, and of the light it is desired to reproduce. Then, taking into account the dispersion of the prism, which is determined by measuring a line spectrum formed at S^1 (photographically is easiest), the relative opening at each wave-length is determined to perform the desired reduction, and this is reduced to angular units.

In the instrument as constructed by us the spectrometer and camera attachment were firmly screwed on a large, heavy board. The sector was mounted on a separate flat metal plate, which in turn was supported on uprights to the board. The metal plate, pierced with an opening at S^1, is fastened to the camera body, but in such manner that the latter is under no strain. The motor to turn the sector disc is fastened to the base-board. A small pivoted metal plate F carries the white surface to be illuminated by the standard light source.

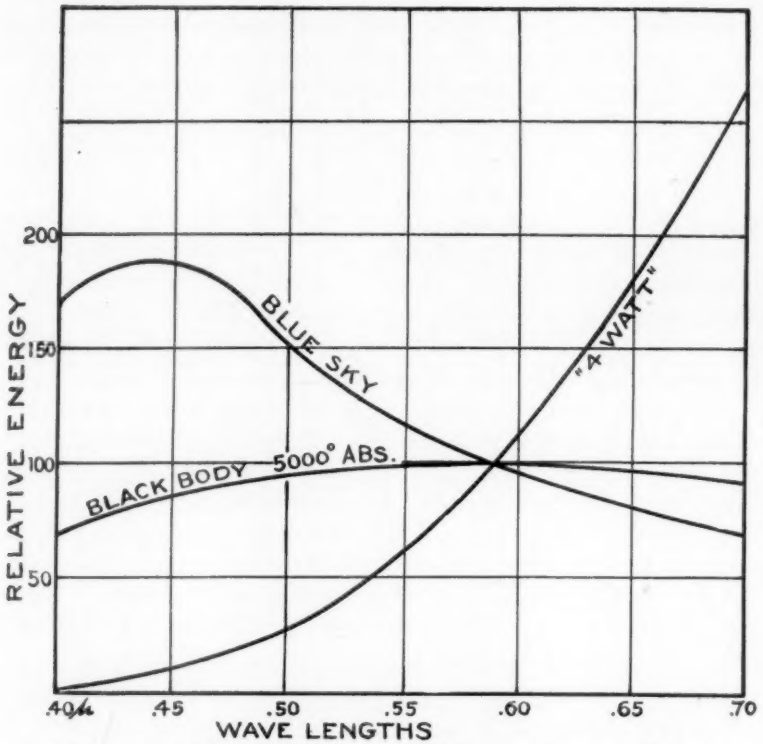
The light source used by us so far has been a 100-candle-power carbon incandescent lamp, accurately matched to the color of the "4-watt-per-candle" lamps used as the photometric standard of this country and maintained by the Bureau of Standards. These lamps were, for reasons given elsewhere,[1] taken as having the relative energy distribution of a black body at 2080° absolute, as calculated from the Wein equation

$$I = c_1 \lambda^{-5} e^{-\frac{14500}{\lambda T}}$$

[1] *Philosophical Magazine*, December, 1912.

Thus far two sector discs have been cut, one to give the light of a "black body" at 5000° (white light) and the other the light of a light blue sky, as determined from spectrophotometer data.[2] The energy distribution of the 4-watt lamp, the 5000° body, and the blue sky are shown in Plate I, plotted, according to the usual convention, as equal at .59μ. For our present purpose

PLATE I.

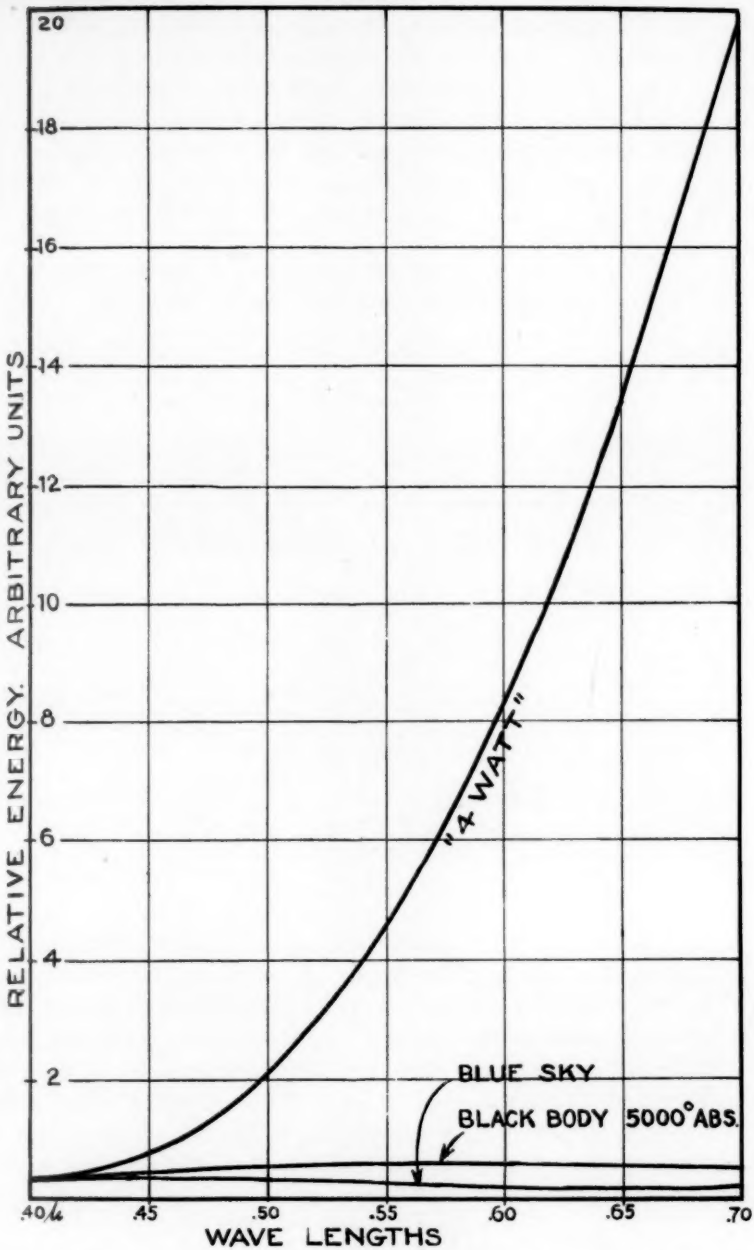


Relative energy distribution, standard "4-watt" lamp, "sunlight" and "blue sky."

they should be replotted as equal to the extreme blue end (.4μ), as is done in Plate II. In this figure the area between the energy distribution curve of the light desired and the 4-watt lamp energy distribution curve represents the energy which must be cut out by the sector. The ratio in this figure of $\frac{\text{energy of desired light}}{\text{energy of standard light}}$

[2] *Transactions Illuminating Engineering Society*, April, 1910.

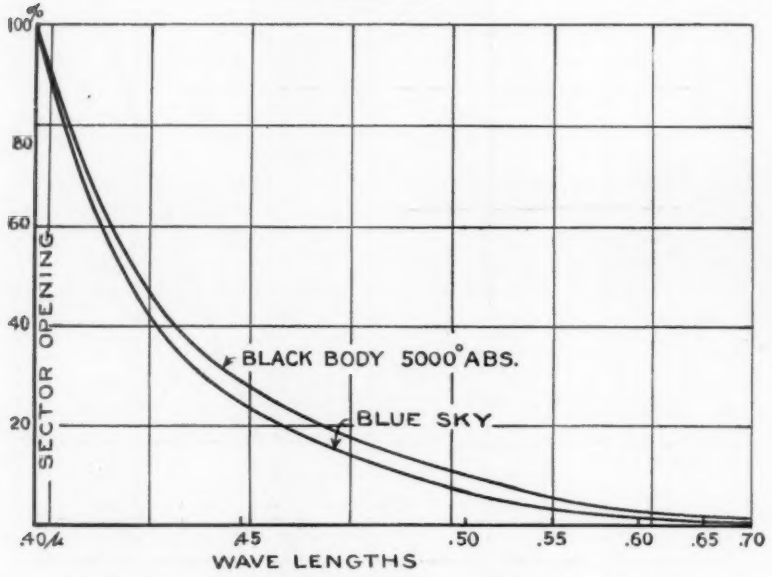
PLATE II.



Relative energy distribution of radiation from standard lamp, black body, at 5000° abs. and blue sky plotted equal as .40μ.

at any wave-length is the opening of the sector at that wave-length. The openings called for are shown in Plate III, plotted on the prismatic scale of the instrument, before being reduced to angular measure. It is advantageous to have the periphery of the disc at the red end of the spectrum, because in reducing to angular units the actual opening at the red end, which is necessarily small, is kept as large as possible in actual dimensions. Each disc has eight openings, each cut in a separate accurately milled sector,

PLATE III.



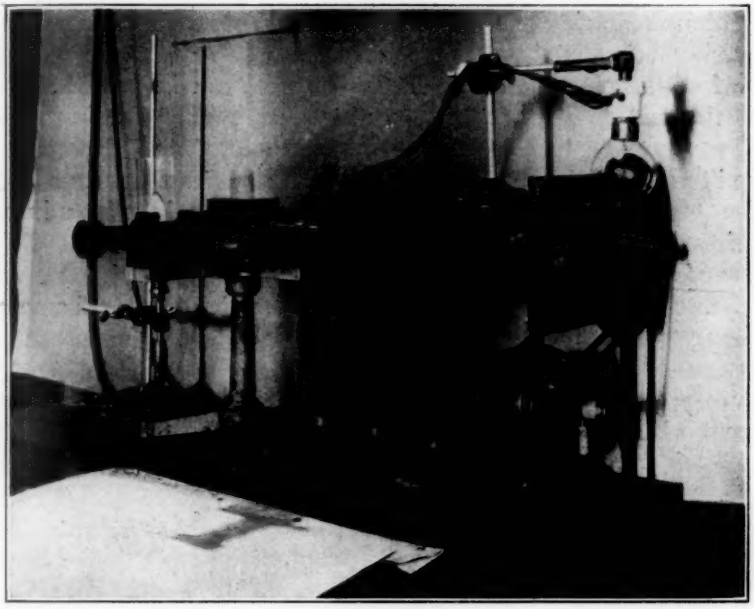
Sector openings to produce "sunlight" and "blue sky." Plotted with regard to the disposition of the prism, but not in angular units.

the sectors being filed to shape over a steel form first laid out with great care, cut, and hardened. A mark is scratched on one of the sectors at the position corresponding to some convenient wave-length, such as the sodium line, so that the apparatus may be easily put in correct alignment at any time by a slight turn of the wave-length drum.

A slight correction necessary to the instrument is that for the selective absorption of the prism. This should be accurately determined and introduced into the calculation of the disc openings.

In our own instrument correction has been provided for so far by the introduction of a block of glass similar to the prism and of the same equivalent thickness on the side of the light being compared with the spectrophotometrically built-up one. This is perfectly satisfactory for the class of work for which the instrument was designed. Future discs will, however, have embodied in them the correction as determined by the spectro-

FIG. 2.



Apparatus for the spectroscopic synthesis of color.

photometer. An instrument using a quartz prism would probably obviate the necessity for this correction, which is negligibly small for most purposes.

Among the uses of the device comes first that for which it was designed, namely, the establishment and preservation of an absolute standard of white light for the industrial production of "daylight glass."[3] It should, as well, fill a need that has long been recognized in physiological optics. Such experiments as de-

[3] JOURNAL OF THE FRANKLIN INSTITUTE, May, 1914.

termining the "neutral point" of color-blind observers have hitherto been dependent on the use of sunlight or cloud light, of variable and uncertain character. Three-color-mixture and other color-measuring experiments can by this device be put on a far more exact basis than ever before. In fact, the apparatus as described consists practically of one-half of a color-mixture apparatus. For instance, three slits or three incandescent lamp filaments might be arranged on a similar camera body placed at right angles to the one now used, their light being directed by a totally-reflecting prism over half the field through the same dispersing prism and so create a red-green-blue mixture in one half of the photometric field. Ample light can be provided for so that not only spectrum colors but even colored fabrics could be measured by placing them upon F, whereby they would always be illuminated by the same white light. Such improvements over the classical color-mixture devices as measuring the mixing primaries radiometrically suggest themselves. Another possible use of the instrument is in connection with physical photometry The surface F may be replaced by a long, straight carbon filament, the sectors cut to a "visual luminosity" curve, and the apparatus is ready for the calibration of absorbing media transmissions by pure energy measurements. These and other uses of the instrument will be reported on when the writers have the opportunity to work them out.

Copper Ore. ANON. (*Eng.*, xcvi, 2500, 736.)—Extensive deposits of copper ore have been discovered on the south side of Stora Blasjon, Frostviken, Jämtland, Sweden. The ore is reported to be of high quality and it reaches the surface for distances of as much as 600 feet.

THE PROBLEM OF MOTOR GASOLINE.*

BY
JOHN WINKLER.

CALIFORNIA petroleum is one of the large sources for gasoline, and yet probably 80 per cent. of it is too thick for any explosive mixture and "a sootless burn" in the cylinder. To depolymerize the heavy hydrocarbon oils down to their simplexes —somewhat analogous to the depolymerization of synthetic rubber back to isoprene—the following experiments were carried out:

First, by way of explanation, "cracking" of these oils by mere superheating has proved totally unprofitable in California factories; and so have all kinds of pyrogenic experiments in this laboratory (*i.e.*, passing the vapors with hydrogen through hot tubes containing various metals). The results have not shown promise, as the products go largely into the sludge in refining, and have penetrating odors. The oils show great tendency to thicken when heated, especially in contact with various substances, as air, alkali, concentrated sulphuric acid, and various salts, as aluminum chloride. The best results, of course, are obtained by distillation in an atmosphere of hydrogen. In addition to the unsaturated "cyclic" bodies (chain with closed ends), and the sulphur and nitrogenous compounds, we have considerable benzol ring bodies with side chains—as the mesitylenes—forming the turpentine substitutes. The asphalt, of course, occurs therein as a colloid,[1] and is eliminated at the start by fractional steam distillation.

Experiment 1. *Effect of Corona.*—A glass tube 2¼ inches diameter by 3½ feet long, wrapped with wire gauze, with a ¼-inch copper rod suspended co-axially through its centre, was used as a hot vapor chamber, while at the same time the inside rod and outside gauze were kept at a potential of from 25,000 to 30,000 volts by dynamo and high potential transformer. When

* Communicated by the Author.

[1] *Z. Ang. Ch.*, 1913, p. 609.

the room was darkened a continuous bright bluish glow was evident throughout the tube,—*i.e.*, a corona. Through this glow (air removed) various California heavy distillates were distilled repeatedly, with a large excess of hydrogen (dry and moist), the object of the corona being to ionize the hydrogen.[2] Practically no change could be detected in the oils after repeated slow distillations through the above chamber.[3]

Experiment 2. *Effect of Arc.*—The Birkeland-Eyde process was applied to these oils in an atmosphere of hydrogen. The oils, both liquid and gaseous, were passed through with increasing speed, to shorten the time in the arc. The carbons were hollow, and hydrogen was passed inward through both. They were kept cool by a water jacket. The results were variable, but in every case the oils were reduced to non-condensable gases and a cloud of fine carbon.

Experiment 3. *Effect of Steam and Aluminum under Pressure.*—Very fine aluminum dust was mixed with various heavy California oils to a "suspension," and these mixtures subjected to a pressure of 110 pounds per square inch with steam in a heavy, specially constructed machine. They were also agitated, and at the same time heated to various temperatures (indicated by thermometer) up to their cracking points. The purpose of the aluminum and steam was to generate nascent hydrogen within the oil. A variety of attempts indicated no success. The aluminum was not amalgamated.

Experiment 4. *Effect of Reduced Nickel Oxide and Hydrogen on the Aërated Oil.*—According to Charitschkoff, better results at "cracking" Russian petroleum were obtained by first oxidizing the oil.[4] Heavy California oils were heated, and aërated (by drawing air through them) for two to three days, to oxidize them and to generate petroleum acids (the purpose of this oxidation also being to introduce carboxyl groups, with the possibility of splitting out water with the hydrogen afterwards, and leaving the rest of the broken molecule to unite with the

[2] The dielectric constants of hydrogen and hydrocarbon vapors and air were found to be not very different.

[3] The suggestion of passing SO_2 and air through the above chamber was not tried, but was tried with a large ozonizer with only partial effect. G. Lunge, "Sulfuric Acid and Alkali."

[4] "Petroleum," 1913, p. 748.

excess hydrogen). The aërated oils were subjected to the now well-known hydrogenating process of reduced nickel oxide and hydrogen (said to be least sensitive to sulphur compounds [5]), but without success. Iodine was substituted for the nickel oxide with no better results.

Experiment 5. *Effect of Rhodium Black and Hydrogen.*—First, active platinum black, made according to the Loew process,[6] has been shown to be a good catalyst to hydrogenate pure benzol and pure benzine. It is, however, poisoned by sulphur bodies.[7] The work was corroborated in this laboratory perfectly, but California oils contain sulphur, and so do not hydrogenate.

Second, G. Bredig has shown that rhodium metal acts as a catalyst to break down formic and acetic acids to H and CO_2, etc., and that sulphur bodies are favorable to its activity.[8] Rhodium black was made (by the Loew process), and tried out on California oils under parallel conditions, but failed to hydrogenate in the least.

An easy experiment which is suggested here is to find a possible antidote for the poisonous effect of sulphur bodies in benzol on platinum black. Could we hydrogenate the oils, it is obvious that they would then depolymerize more readily.

UNIVERSITY OF CALIFORNIA, May, 1914.

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[5] *Z. Ang. Ch.*, 1913, pp. 561–606.
[6] *Ber.* 23, p. 289.
[7] *Ibid.*, 45, p. 1471 *et al.*
[8] *Oest. Ch. Ztg.*, No. 14 (1911), p. 266.

Russian Platinum Production in 1913. (*Board of Trade J.*, March 19, 1914.)—H. M. Commercial Attaché for Russia reports that the yield of platinum in the Urals continued to decrease during 1913 in spite of the very high prices prevailing. According to the *Torgovo-Promyshlennaya Gazeta* (St. Petersburg) of February 24th, the production in 1913 was 299 pouds 18 funts, as compared with 337 pouds 9 funts in the previous year. (Forty funts = 1 poud = 36 pounds.)

The Deformation of Water Conduits. C. GUIDI. (*Accad. Sci. Torino,* atti xlviii, 357, 1912.)—Considers the deformation of an iron tube having a wall thickness of 0.02 *r* or 0.01 *r* where *r* is the radius of the iron tube. The conduit is assumed to be supported over an arc of 40°, offering a uniform resistance. The deformation is due partly to the hydrostatic pressure and partly to the weight of the water. If *r* is 100 cm., a tube 2 cm. thick shows very small deformations; but when the thickness is only 1 cm. the limits of stability are approached.

The Experimental Gallery at Derne, Westphalia. BEYLING and ZIX. (*Glückauf,* xlix, 433.)—The natural gas used in the explosion tests in the experimental gallery which was established at the Consolidation Colliery in 1896 having become exhausted, a new gallery has been erected at Derne, near Dortmund, where natural gas can be obtained containing 88.9 per cent. methane, 9.3 per cent. nitrogen, 0.9 per cent. carbon dioxide, and 0.9 per cent. oxygen. The main gallery is built up of boiler plate; it is circular in section, 1.8 metres diameter; present length, 100 metres, to be extended to 300 metres. The smaller gallery is elliptical in section, 1.83 metres high, 1.32 wide, and 25 metres long; it is built up of three layers (six in exposed parts) of tarred pitch pine boards lined inside with sheet iron and bound outside by half-rings of I-iron; the one end is closed by a block of brickwork, through which the ventilator pipe is carried; like the main gallery, it is provided with observation windows. There is, further, a third gallery, 4 metres by 1.8 and 1.4 metres, for special experiments, and an iron conduit for safety-lamp testing by Schondorf's method. A magazine for explosives is near. The plant is described, but no new experiments are yet mentioned.

Combined Neon and Mercury-vapor Tubes. ANON. (*Electr. Engineering,* x, 23.)—In the arrangement as applied by G. Claude neon and mercury-vapor tubes are successively lighted and extinguished, so that, owing to the condensation of the mercury-vapor by cooling, red, blue, and other colored lights are obtained.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

[ABSTRACT.]

OBSERVATIONS ON FINISHING TEMPERATURES AND PROPERTIES OF RAILS.*

G. K. Burgess, J. J. Crowe, H. S. Rawdon, and R. G. Waltenberg,
Bureau of Standards.

THE main objects of this investigation were to determine, from measurements taken in representative rail mills, the present American practice regarding the temperatures at which rails are rolled; to demonstrate the ease and accuracy with which such temperatures may be measured; to find out what the "shrinkage clause" in rail specifications really means; and, finally, to determine for rail steels some of the physical properties, particularly those of interest in manufacture.

Observations were taken with an optical pyrometer of ingot and finishing temperatures of rails in four representative mills.

There is practical uniformity among the several mills for the rolling temperatures of ingots for steel rails, the range being from 1080° C. (1975° F.) to 1140° C. (2085° F.). There is no very considerable difference among the finishing temperatures of the rails as observed at the hot saws for several mills, the range being about 880° C. (1615° F.) to 990° C. (1815° F.), or, in other words, the four mills all finished their rails to within 50° C. of 935° C. (1715° F.) on the average. This temperature of 935° C. is 270° C. (520° F.) above the mean value, 665° C.

* This is a summary of a paper to be published shortly in full as a *Technologic Paper* of the Bureau of Standards with the following contents: 1.. Introduction; 2. Importance of Limiting Temperatures of Rolling Rails; 3. Methods of Measuring Rail Temperatures; 4. Wickhorst's Experiments; 5. Measurements of Ingot and Finishing Temperatures; 6. The Samples and Chemical Analyses; 7. Mechanical Properties of Rails; 8. Melting Temperatures of Rail Steels; 9. The Critical Ranges of Rail Steels; 10. Observations on the Microstructure; 11. Temperature Distribution in a Cooling Rail; 12. The Expansion of Rail Steels; 13. The "Shrinkage Clause" in Rail Specifications; 14. Summary and Conclusions.

(1230° F.) of the critical ranges of these rail steels. Concerning the distribution of temperatures within the head of a cooling rail, it is shown that the centre of the head is some 50° C. (120° F.) to 60° hotter than the optical pyrometer reading at 935° C., therefore the centre of the head is finished, on the average, at about 325° C. (615° F.) above the critical range for 100-pound sections.

Chemical analyses and microphotographic examinations were also made and the mechanical properties determined for a number of samples of rail the rolling of which had been observed. From a comparison of these few observations there appears to be not a sufficient degree of correlation to warrant associating very specifically any of the characteristics defined by these three methods of examination, either with the temperatures of rolling here observed or with each other.

The following thermal properties of these rail steels were determined in the laboratory:

The critical range on heating is located (maximum) to within 7° C. of 732° C. (1350° F.) for the 10 samples of O.H. and Bessemer steels examined. On cooling, the critical range lies between the limits 680° C. (1256° F.) and 650° C. (1202° F.).

The melting or freezing range for rail steel extends from about 1470° C. (2680° F.) to nearly the melting-point of iron, located at 1530° C. (2786° F.).

The expansion for O.H. and Bessemer steels is not the same. Above 800° C. (1470° F.) the expansion for both increases linearly with temperature, and the linear coefficient per degree centigrade has the following mean values from 0° to 1000° C.:

(1) For Bessemer steel (carbon .40 to .50%): $\alpha = 0.0000146$ to
(2) " open-hearth " (carbon .65 to .75%): $\alpha = 0.0000156$ to 0.0000161

The average composition of the Bessemers was carbon = 0.40 to 0.50 and manganese = 0.76 to 0.93; of the open-hearths, carbon = 0.66 to 0.70 and manganese = 0.66 to 0.72.

The American Society for Testing Materials in 1909 limited the shrinkage allowance on 100-pounds sections to 6¾ inches in 33 feet, or to an equivalent of 1947° F. (1064° C.) for O. H. and 2055° F. (1124° C.) for Bessemer rails. This specification is still in force. Such a shrinkage clause therefore does not

serve the avowed purpose of limiting the finishing temperatures to a value slightly above the critical range.

In conclusion, it should be emphasized that the various series of observations recorded in this investigation are of but a preliminary nature and do not pretend to solve the question of the relations between temperature of rolling and the properties of rails. It would seem desirable to make a much more complete and comprehensive study of the various matters mentioned and of related questions than has hitherto been attempted, and on a scale commensurate with the importance to the community of the problem of sound rails.

[ABSTRACT.]

THE ANALYSIS OF PRINTING INKS.

By J. B. Tuttle and W. H. Smith.

A PROCEDURE of analysis of printing inks has been developed which, during the years in which it has been used, has been found to be very satisfactory.

By means of suitable solvents, the ink is divided into two parts: oil and pigment.

The oil fraction is analyzed for unsaponifiable matter and rosin. The former may consist of mineral oils or the hydrocarbon portion of rosin oil. A qualitative test for rosin oil and rosin is given.

The analysis of the pigment fraction will depend very largely on the color of the pigment. Methods are given for the determination of the principal constituents of the more common inks, such as black, red, blue, green, etc.

The paper contains a brief discussion of the relation of aniline dyes in the inks to the paper. This covers the question of the permanency of the blue dyes used to neutralize the yellow color of the oil, and emphasizes the necessity for a careful selection of the dyes to be used. Several methods for the determination of the permanency to light of the various colored pigments are given.

A few special tests for some abnormal constituents of ink are given. They are not considered to be very important.

Figures are given showing how closely one may expect duplicate determinations on the same sample to check, based on the experience of this Bureau during the past two or three years. It is claimed that these checks are at least as close as the manufacturer can duplicate his ink, and may therefore be considered satisfactory for practical purposes.

Fuller's Earth.—A report on fuller's earth, by Jefferson Middleton, of the United States Geological Survey, has been published as a chapter from "Mineral Resources" for 1913, and copies will be sent to interested persons free, on application to the Director of Survey at Washington, D. C. The value of the fuller's earth mined in 1913 in the United States was $369,750, against $305,522 in 1912, an increase of $64,228. The production in 1913 was but $13,374 less than that of 1911, the year of maximum production. In quantity and value of production Florida was the leading State in 1913, Georgia was second, Arkansas was third, and Massachusetts fourth. Florida and Georgia together contributed over 97 per cent. of the quantity and value of the fuller's earth marketed in 1913.

The Operation of the Panama Canal Locks. ANON. (*Eng. News,* lxx, 1323.)—A large amount of power is used, at different points along the canal, and this article chiefly treats with the methods employed to control the various operations, to record the various water levels and to interlock different devices. At the Gatun dam there is a 7500 kv.a. 2200-volt hydro-electric generating station; at Miraflores there is an emergency station of about half the size. A two-circuit 44,000-volt transmission line runs across the Isthmus. A large amount of power is used at various points for working the locks, for lighting, power, and traction. The scheme of connection throughout uses a double bus-bar with duplicate oil switches so that one can be disconnected for cleaning or repair. There are in all 36 substations at different points.

THE FRANKLIN INSTITUTE

AWARD OF THE ELLIOTT CRESSON MEDAL TO DISTINGUISHED SCIENTISTS AND TECHNOLOGISTS.

At a stated meeting of the Institute, held on the evening of Wednesday, May 20, 1914, Dr. Walton Clark, President of the Institute, presiding, the Institute's Elliott Cresson Medals were awarded to:

PROVOST EDGAR FAHS SMITH, PH.D., SC.D., LL.D., in recognition of his leading work in the field of electrochemistry, of his many contributions to the literature of chemical science, and of his great service in university education.

ORVILLE WRIGHT, B.S., LL.D., in recognition of the epoch-making work accomplished by him, at first together with his brother Wilbur and latterly alone, in establishing on a practical basis the science and art of aviation.

PROF. KARL PAUL GOTTFRIED LINDE, PH.D., in recognition of his scientific investigation of the processes of refrigeration and the liquefaction of gases, and of his inventions of machinery for applying these processes in the manufacture of ice and for the purposes of cold storage.

JOSEF MARIA EDER, PH.D., in recognition of his important original researches in the science of photo-chemistry and of his many valuable contributions to the literature of that science and of graphic arts.

The work of Drs. Smith and Wright was described by Dr. Harry F. Keller, who presented them to the President of the Institute, from whom they received the medals awarded them. The work of Drs. Eder and Linde was described by Mr. Louis E. Levy.

In opening the meeting, the President of the Institute, Dr. Walton Clark, said: This is a stated meeting of The Franklin Institute. We are honored by the presence of two gentlemen to whom the Institute authorizes and instructs us to present the Elliott Cresson Medal in recognition of their distinguished work of science. The Chair recognizes Dr. Keller to present Dr. Edgar Fahs Smith, Provost of the University of Pennsylvania, for the Elliott Cresson Medal.

DR. KELLER: Mr. President, the Committee on Science and the Arts has once more scanned the rolls of our contemporaries who have attained eminence in the field of pure and applied science which this Franklin Institute of ours has always striven to promote, and in choosing and recommending the names

of the Elliott Cresson Medallists of this year the committee was confident that they would be accepted as in every way worthy of being ranked with those on which this honor has been conferred in former years.

Of the four scientists and inventors to whom this highest award of the Institute has been made in accordance with the committee's recommendation, two are Europeans, while the other two are of our own nationality. All four of the medallists have expressed their gratification and appreciation in accepting the award, and our two distinguished compatriots are giving us the pleasure and the honor of their company to-night in order that they may receive the medals from your hands. And in both instances the presence of the recipient is attended with a circumstance that much enhances our joy in the welcome we extend to him; in the one, our guest is a fellow-townsman and, I believe, the first on whom the Elliott Cresson Medal has ever been bestowed for his life-work; while in the other a busy inventor paused in his work and made the long journey from Dayton, Ohio, to be present on this occasion.

Mr. President, the work of the scientific investigator and of the director of a great university laboratory may be lacking in the picturesque and dramatic features, and, as a rule, is not calculated to arouse popular attention and enthusiasm, but, nevertheless, it not infrequently yields results of the highest value, not only in adding to the sum of our knowledge, but also in promoting the material welfare of mankind. It is no exaggeration to say that there are few inventions that minister to our needs and comforts in which advantage has not been taken of scientific work, the primary purpose of which is to establish truth for its own sake. Thus the marvellous growth and development of the electrical industries was made possible only through the great discoveries made by investigators like Faraday and Henry; and the resplendent triumphs of modern synthetic chemistry had their source in the researches conducted by such master-minds as Liebig, Hofmann, and Emil Fischer. It is the quiet work steadily going on in the laboratories of our institutions of learning that is the main-spring of the rapid advances in our industries and manufactures. The prominent part which chemical research has had in the development of our natural resources is clearly reflected in an interesting volume just published, from the pen of one of our medallists. Its title is "Chemistry in America," and it tells in a fascinating manner of the achievements made by American chemists during the first century of our national existence. With characteristic modesty, however, the author has refrained from including in this account the splendid work which he and his students have done in the nearly four decades that have since elapsed. It was my good fortune to witness, first as a student, then as an associate, and later as an interested spectator, the uninterrupted chain of beautiful and valuable researches he conducted during this long period, for the most part in the chemical laboratory of the University of Pennsylvania. The results of this work are recorded in more than 150 contributions to the principal periodicals devoted to chemistry, and in a number of books. The earlier publications were mostly on synthetic-organic and mineralogical subjects, but gradually

these were abandoned in favor of more original and more extended lines of work which led the enthusiastic investigator into new or neglected fields of inorganic chemistry. In the brief space of time allotted to me it is impossible to attempt even the merest sketch of these fruitful researches. The most important of them may be classed under four heads, viz., electrochemical analysis, the rarer metals, the complex inorganic acids, and the determination of atomic weights. In electrochemical analysis our medallist now stands *facile princeps;* for not only was he one of the pioneers in this branch, but he has assiduously and indefatigably continued its cultivation. We are indebted to him for a great number of excellent electrolytic methods, for some of the most serviceable forms of apparatus used in such work, and for a standard text-book on the subject. The researches on the rare elements and the complex inorganic acids have yielded innumerable interesting and important results, and thus greatly added to our knowledge of subjects which only the most resourceful of experimenters can venture to attack. The same is true also of the determination of atomic weights; indeed, it is one of the proudest achievements of our medallist that his extended work in this direction has yielded so many values which closely approach, and in some cases exactly agree with, the now accepted standards of these natural constants.

It is my understanding, Mr. President, that the Elliott Cresson Medal is awarded for the eminent services the recipient has rendered to chemical science as an investigator, and I must for this reason refrain from referring to his no less distinguished activities as a teacher, as an author, as a leader of men, and as the revered Provost of one of our greatest universities. But I am sure that is quite unnecessary before an audience such as this.

It is with very great pleasure that I have the honor of presenting to you the eminent chemist, Provost Edgar Fahs Smith, of the University of Pennsylvania.

DR. CLARK: Dr. Smith, in the name of The Franklin Institute, moved thereto by its Committee on Science and the Arts, and in recognition of your distinguished services to mankind rendered in the field of science, I have the honor to present to you the Elliott Cresson Gold Medal, the highest honor in the gift of the Institute.

DR. CLARK: The Chair again recognizes Dr. Keller to present Dr. Orville Wright for the Elliott Cresson Medal.

DR. KELLER: Mr. President, the past two decades have been prolific in achievements which in former times would have been considered as quite beyond the range of human endeavor. Problems which had been abandoned by investigators and inventors because of apparently unsurmountable difficulties have not only been successfully solved, but the popular mind has become so familiar with the results that these are no longer regarded as wonders.

To mention but a few instances we think nothing of ordering a taxicab by wireless message as our liner approaches port; the liquefaction of what we used to call the "incoercible gases," such as atmospheric air, is rather a

tame and commonplace performance now; we have ceased to worry about the exhaustion of the Chilean nitre deposits since the fixation of atmospheric nitrogen has been made a commercial success; moving pictures must be in natural colors and accompanied by speech or song to arouse special interest; and nothing short of crossing the Atlantic will now suffice to demonstrate the high degree of proficiency that has been attained in aërial navigation.

Nevertheless, it is true that of all inventions of modern times none has aroused greater curiosity, none taxed the ingenuity, the endurance, and the daring of men in a higher degree than the conquest of the atmosphere. Through the ages men had dreamed of a mechanism that would enable them to soar and simulate the flight of birds. From the cunning Dædalus of old down to our own times innumerable attempts to accomplish this most alluring aim have been recorded. It was not, however, until the beginning of this century that the mechanic arts had advanced sufficiently to permit its realization. Valuable pioneer work in gliding flight had indeed been done by those ill-starred enthusiasts, Otto Lilienthal, of Germany, and Percy Pilcher, of England, as well as by our own Octave Chanute; and the possibility of mechanical flight in a heavier-than-air machine had been foreshadowed by the experiments of Langley. But the construction of an apparatus that was capable of carrying a man and of being steered in every direction is an achievement that must be credited to the genius and the undaunted energy of two brothers, natives and citizens of the state of Ohio. Beginning in 1900, they conducted a series of experiments, extending over nearly three years, on the undulating sand-dunes near the Kitty Hawk Lighthouse, N. C. Among other results this work led to the invention and development of two essential features of the aëroplane, viz., the front horizontal rudder for steering in a vertical direction, and the device for balancing the machine in flight by flexing the outer ends of the supporting planes. In the meantime the gasoline engine for automobiles had been so far perfected that with suitable adaptation to the aëroplane it enabled the inventors to design a machine combining relatively high power with low weight and capable of carrying a man in flight. The first successful flights with such an aëroplane were made in December, 1903, and each of the brothers in turn was at the helm. But shortly after landing from a flight of nearly a minute's duration and extending over 852 feet the plane was caught in a wind-gust and completely wrecked. The possibility of mechanical flight, however, had been demonstrated, and, as is well known, the aëroplane has since that time been vastly improved in power, speed, endurance, and safety. Men of many nations have had a share in this truly wonderful evolution, but among them the original inventors were always in the forefront.

The one great desideratum that still remains is perfect safety under all conditions, and to this end the medallist of the evening is bending all his energies; so that flying shall become as safe as the usual means of locomotion on land and sea. For this crowning triumph of aviation we look with confidence, Mr. President, to the great inventor and intrepid aviator. I have the honor of presenting to you Doctor Orville Wright.

DR. CLARK: Dr. Wright, in the name of The Franklin Institute, moved thereto by its Committee on Science and the Arts, and in recognition of your distinguished services to mankind rendered in the field of science, I have the honor to present you with the Elliott Cresson Gold Medal, the highest honor in the gift of the Institute.

DR. CLARK: The Institute has awarded the Elliott Cresson Medal to two other distinguished gentlemen, not residents or natives of America—Dr. Josef Maria Eder, Imperial Court Councillor of Austria, of Vienna, Austria, and Dr. Karl Ritter von Linde, of Munich, Germany. These gentlemen have written in appreciation of the distinction conferred upon them by the Institute, and regretting their inability to be present to personally receive the medals. Their absence shall not rob us of the opportunity of hearing something of them and their work, however, and to this end the Chair recognizes Mr. LEVY.

In presenting the work of Dr. Eder, Mr. Levy said: Mr. President, it has been said that the art of printing is the art preservative of arts, and in the same spirit it may be said that photography is the art preservative of nature. For no formula of words, however accurate and detailed, can preserve the semblance of an object of any kind so perfectly as a picture, and no picture can be as true to nature as a photograph.

The art of photography has become not only a method of portraiture, a means of preserving a record of appearances, but also a potent factor in the dissemination of intelligence, a vehicle of popular instruction, an agency in widening the compass of the æsthetic arts and of raising the culture level of the masses of the people. So universally has the product of the photographic art, in all the ranges from the picture post-card to the moving-picture show, become a feature of our modern life, that, in distinction from those earlier stages of civilization which we recognize as the Stone Age, the Age of Bronze, the Iron Age, our present epoch might fittingly be characterized as the Pictorial Age.

The beginnings of the modern graphic arts date back to the tentative efforts of scientists and experimenters over a century ago, which were continued and amplified by their successors during the first half of the nineteenth century. But it has been only within the period of the passing generation that the advances made in photo-chemical science have opened the way to that progress of the art which is spreading its products through all the countries on the globe. This progress, through a combination of the camera and the printing press, has in turn given rise to that great expansion of the pictorial art which is so manifest on every hand in the form of illustrated newspapers, magazines, and books, and which has given the graphic art industry not only a place as an educational agency, but also brought it to a position of great economic importance.

Many workers in every land of civilization have contributed each a share in widening the field of the photo-reproductive arts, some through their researches in photo-chemistry, others through advances in the application of that science. A large and in many respects a peculiarly significant share in

both directions has been contributed by an eminent photochemist in Austria, Dr. Josef Maria Eder, Director of the Royal-Imperial Institute for Research and Instruction in Photography, established in Vienna. That institution, founded by Dr. Eder, under the auspices of the Austrian government fifteen years ago, soon achieved, and under his direction has retained, a leading position as a centre of photochemical science and technology in continental Europe.

Dr. Eder has been identified with the progress of the graphic arts throughout the period of their contemporary development. His contributions to the literature of photo-chemistry date from 1876, when he was but 21 years old, and from that time to the present his researches have been fruitful of many important additions to the science of photography, and the result of his investigations, freely given to the world through his books and through his writings in periodical literature, have greatly furthered the progress of the art.

The Committee on Science and the Arts of the Institute, fully cognizant of the service which has thus been rendered toward the upbuilding of the modern graphic arts, recommends to the Institute that the Elliott Cresson Gold Medal be awarded to Court Councillor Dr. Josef Maria Eder, of Austria, in recognition of his distinguished leadership in that direction.

In presenting the work of Dr. Linde, Mr. Levy said: Last Friday evening The Franklin Institute, together with a number of other technological societies, joined in a meeting at which the principal topic of discussion was the influence which science, invention, and engineering had exerted, and continued to exert, in the development of modern civilization. As was so clearly pointed out on that occasion, this development has inevitably been attended by an increasing complexity of our modern life, which, in its turn, has reacted to present new problems which science has been called upon to solve, new requirements which the inventor has been called upon to meet, and new complexities which the scientific engineer has been called upon to adjust.

Not the least important, and perhaps the most pressing, of these requirements has been that of adjusting the food supply of cities to meet the exigencies which have arisen along with our modern system of coöperation in industry and the coincident growth of great centres of population. To this end it became necessary to store food products in large quantities at convenient points and to preserve these products from decay during storage before their final distribution. Refrigeration was clearly the most desirable method for the purpose, but the problem in this case was not only to produce the necessary low temperature on a sufficiently large scale, but to accomplish this at a cost within the limits of commercial practice. This all-important need was early sought to be met by inventors on both sides of the Atlantic, but remained to be solved by a scientific engineer in Germany, Karl Paul Gottfried Linde. As far back as 1870, while Professor of Engineering at the Technical High School in Munich, Dr. Linde, through his study of thermodynamics applied to refrigeration, pointed the way to the desired end, and in the course of that decade, through the application of great in-

ventive skill and indefatigable industry, he succeeded in developing the ammonia process of ice making and in completing the machinery for the purpose. Dr. Linde was the first to produce ice on a commercial scale, and has been largely instrumental in developing the cold-storage practice of the present day.

Through Dr. Linde's system of regenerative refrigeration, the means were accorded for the liquefaction of the permanent gases, including not only air but also oxygen, and even helium. He was the first to produce liquid air by continuous process and on a large scale, and by a modification of this process he has made possible the economic production of oxygen for practical purposes.

The Committee on Science and the Arts of The Franklin Institute, availing itself of an occasion to testify its high appreciation of the work which I have here but briefly indicated, recommends to the Institute that the Elliott Cresson Gold Medal be awarded to Professor Doctor Karl Paul Gottfried Linde for his leading and directive work in the science and art of refrigeration.

DR. CLARK: The medals awarded to these distinguished European scientists will be forwarded to them through our State Department at Washington.

The medallists who are with us this evening have consented to address us on subjects with which they are, among all men, most familiar.

I take pleasure in introducing Dr. Edgar Fahs Smith, who will speak on the subject of "SCIENTISTS FROM THE KEYSTONE STATE."

DR. SMITH: Before reading the few paragraphs which I have on these pages, I feel that I must express to you here publicly my sincere thanks for the honor which you and the Institute you represent have shown me to-night. If the work I have done has merited this recognition from your hands, then, sir, I feel it incumbent upon me to say that that work could not have been performed without the hearty coöperation, the encouragement, and the sympathy of my students, many of whom are in this audience this evening, and among them Dr. Keller, who so kindly presented me to you for this honor.

(Dr. Smith here read an able paper, in which he reviewed the accomplishments of the State's most noted scientists.)

DR. CLARK: Dr. Smith tells us that Pennsylvania has produced notable men of science, and Dr. Smith knows; and that she is still producing notable men of science, and that their voices are still heard in this Hall, you have just witnessed.

I have now great pleasure in introducing Dr. Orville Wright, who will speak to us on the "STABILITY OF AËROPLANES."

DR. WRIGHT: It is with feelings of deep appreciation that I receive from The Franklin Institute its Elliott Cresson Gold Medal in recognition of work done in the advancement of the art and science of aviation. It is the more gratifying because it is in part given in recognition of work done by my brother Wilbur when we were associated together. I prize the medal highly, and wish to express to the Board of Managers and to the members of the Institute my sincere appreciation.

(Dr. Wright here delivered his address, treating of several phases of the control of the fore and aft balance of flying machines. Dr. Wright's address will appear in a later number of the JOURNAL.)

DR. CLARK: The Institute has been favored, and the JOURNAL OF THE INSTITUTE will be enriched, by this remarkable presentation of the problems involved in the work of Dr. Wright and his distinguished brother.

In the name of the Institute I thank the gentlemen for their interesting lectures.

Brief biographical sketches of the recipients of the medals are given below:

EDGAR FAHS SMITH.

EDGAR FAHS SMITH, PH.D., SC.D., LL.D., was born at York, Pennsylvania, on May 23, 1856. He was graduated in science from the Pennsylvania State College in 1874, and two years later was made Doctor of Philosophy at Göttingen. He was instructor in chemistry at the University of Pennsylvania from 1876 to 1881, and for the two following years was professor in chemistry at Muhlenberg College. He was then appointed to the chair of chemistry at Wittenberg College, which he occupied until 1888. In that year he was called to the University of Pennsylvania, and has held the chair of chemistry since. In 1899 he was made vice-president and in 1910 was elected provost of the University.

Professor Smith's investigations in the field of inorganic chemistry are most remarkable for their great number, the wealth of new results and the wide range of subjects. He ranks easily first among those who have studied the electrochemical methods of analysis; his treatise on this subject is a standard work; and his methods and apparatus are universally used. He has also made numerous important contributions to our knowledge of the atomic weights of the elements, of the various groups of complex inorganic acids, and of the processes used in the separation of the rare earths. He has also devised and improved a considerable number of analytical methods. As author or translator of textbooks he has given to the English-speaking students and chemists a number of valuable and popular manuals, and he has also written most interestingly on subjects of historical chemistry. As the Director of the Harrison Laboratory of the University of Pennsylvania he has trained a great number of successful chemists and chemical engineers.

JOSEF MARIA EDER.

JOSEF MARIA EDER, PH.D., son of Austrian District Councillor Josef Eder, was born at Krems on the Danube, March 16, 1855. Educated at the Technical High-School in Vienna, he devoted himself from his boyhood to the study of the then-budding science of photo-chemistry, and soon distinguished himself by his successful efforts in largely furthering its progress. As early as 1876 he began those numerous contributions to current photographic literature which he has continued to the present time. In 1878 he published the results of his investigations on the "Reactions of Chromic Acid and the Chromates on the Gelatines, Gums, and Sugars," a work which

opened wide the field of study in this direction and which was awarded the prize of the Vienna Photographic Society. In 1879 he published his work on "The Influence of Colored Light on Photography in Natural Colors." In that same year he was appointed lecturer on photo-chemistry at the Technical High-School, and obtained there his academic degree in 1880. While serving in that institution he carried through a series of important researches, the results of which were published in various forms. Especially notable among these results are those presented in his book, published in 1881, on "The Theory and Practice of Photography with Gelatino-Bromides and Iodides," and that of 1883, on "The Chemical Effects of the Spectrum." In 1882 he was accorded the professorship of chemistry at the State Industrial School in Vienna, but he continued without interruption his frequent contributions of important scientific data to the current periodical literature of photography. In 1887 Dr. Eder began the publication of his Year Book of Photography, now universally known as Eder's Jahrbuch, a work he has continued to the present time, steadily advancing it to greater thoroughness and completeness. This annual has gained general recognition as a comprehensive chronicle of the world's progress in the science of photo-chemistry and its practical applications, and presents a most valuable addition to the literature of the graphic arts.

In 1888, under the auspices of the Austrian Government, Dr. Eder organized the now famous Vienna Institute for Instruction and Research in Photography, of which he became, and still remains Director, and which has formed the model for similar schools in Germany, France, and England. The results of his investigations at the Institute have been given to the world in his work on "Photography with Röntgen Rays," published in 1896; that on "Photo-chemistry and Spectrum Analysis," in 1903; his "Atlas of Typical Spectra," 1912; and in that monumental work, his "Complete Handbook of Photography," in four volumes, of which a fifth edition was issued in 1912.

Dr. Eder is Royal-Imperial Court Councillor of Austria, Officer of the Legion of Honor of France, Commander of the Francis Josef Order, of the Swedish Order of Wasa, of the Albrecht Order of Saxony, and so forth,—honors which but reflect that which he has earned through his work.

KARL PAUL GOTTFRIED LINDE.

KARL PAUL GOTTFRIED LINDE, PH.D., was born in Berndorf, Oberfranken, on June 11, 1842. From 1866 to 1868 he was director of the construction department of Krauss and Company's Locomotive Works Munich, Bavaria. In 1868 he was appointed assistant professor at the Technical High-School, Munich, and three years later professor. From 1879 to 1890 he was manager of the Linde Ice-Machine Company.

He was the pioneer in the manufacture of ice on a large scale, and in the introduction of liquid ammonia as the refrigerant in ice machines and cold-storage systems. The refrigerating machinery mostly used at the present time, known as the ammonia "compression" system, is essentially Linde's invention. In applying the principle of self-intensive refrigeration,—

i.e., by utilizing the cold produced by allowing compressed air to expand,—Professor Linde was the first one to liquefy gases like air without the use of other liquefied gases and on a large scale. He also devised an ingenious process for the fractional liquefaction of air by which the bulk of the commercial oxygen is now manufactured. Thus the life-work of this great engineer and inventor includes at least three achievements of the first magnitude: The invention of the almost universally used liquid ammonia ice machine; the construction of the first and most successful liquid air machine, and the devising of the process of making oxygen by its liquefaction from atmospheric air.

ORVILLE WRIGHT.

ORVILLE WRIGHT, honorary B.S. of Earlham College, Indiana, 1909, and honorary LL.D of Oberlin College, Ohio, 1910, was born August 19, 1871, at Dayton, Ohio, and received his education in the common schools and public high-school of that city continuing in attendance until his seventeenth year. Under the lead of his elder brother, Wilbur, four years his senior, he acquired mechanical experience and skill in a small machine shop established by the brothers in Dayton for the repair of bicycles, and from this beginning they gradually developed their ambition and purpose to solve the problem of mechanical flight.

The experiments of Otto Lilienthal in Germany with aëroplanes capable of sustaining a man in gliding flight, during several years previous to 1896, when he was killed in one of his trials; those of Percy Pilcher in England with similar devices during the succeeding years until he, too, met his death by accident in the course of his efforts in 1899, and those of Octave Chanute in this country, who had during that same period safely made over a thousand short flights with gliding planes, spurred the young mechanicians to take up the work and to endeavor to carry it to completion.

They began in 1900, and in their earliest experiments improved on the work of their predecessors by the addition of two vitally important features—that of a front horizontal rudder for steering the planes in a vertical direction, and that of means for balancing the machine during its flight by devices for flexing the outer ends of the supporting planes. These essentials were developed in the course of experiments carried on through three years on the undulating sand dunes near Kitty Hawk Lighthouse, on the North Carolina coast, and brought the inventors to a clear recognition of the fact that with an engine combining a relatively high power with low weight the aëroplane, as they had learned to make it, could be made to carry a man in flight.

By this time the gasoline engines for automobiles had been brought to a point of efficiency closely approaching what the Wrights needed for their purpose; quickly they applied themselves to its further perfection and to combining it with their machine. Constantly difficult, frequently disappointing, and always dangerous was the work to which the earnest inventors were devoting themselves, but at last, in December, 1903, they achieved their purpose, for on the 17th of that month four flights were made,

two guided by Wilbur and two by Orville Wright. The last of these flights, made with Wilbur at the helm, continued for 59 seconds and extended over 852 feet. More would have been done within the next few days, but shortly after the last landing a violent wind gust, sweeping over the bay, caught the aëroplane and wrecked it. But the way had been found. The work of the Wright brothers had shown the possibility of human beings flying through the air at will, and the realization of those possibilities has since followed, as a matter of course. In working towards that realization, men of many nations and in many climes had taken large and honorable parts, and not a few, like the elder of the Wright brothers, have paid for progress with their lives. There was yet, and still is, need for perfect safety in the working of the aëroplane, but this final requisite is also being worked for, and by none with more promise of achievement than by the surviving pioneer of aviation, Orville Wright.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, June 3, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 3, 1914.

MR. GEORGE R. HENDERSON *in the Chair.*

The following report was presented for final action:

No. 2593.—Atwater Kent Ignition System. John Scott Legacy Medal and Premium. Recommendation adopted.

The following reports were presented for first reading:

No. 2597.—G. A. Wheeler's Escalator.

No. 2599.—Coöperation with Research Corporation. Advisory. Adopted.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated Meeting, Board of Managers, June 10, 1914.)

RESIDENT.

DR. ROGER F. BRUNEL, Department of Chemistry, Bryn Mawr College, Bryn Mawr, Pa.

MR. D. J. COLLINS, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pa.

MR. J. PARK MASSEY, Twentieth and Chestnut Streets, Philadelphia, Pa.

MR. WILLIAM MOYN, JR., 115 Chestnut Street, Philadelphia, Pa.

MR. WILLIAM G. WARDEN, 1012 Witherspoon Building, Philadelphia, Pa.

NON-RESIDENT.

MR. C. G. ADSIT, Engineer, Georgia Railway & Power Company, Atlanta, Ga.
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MR. K. G. MACKENZIE, The Texas Company, Bayonne, N. J.
MR. H. B. OATLEY, Locomotive Superheater Company, 30 Church Street, New York City, N. Y.

Changes of Address.

MR. M. DE TEIVE E. ARGOLLO, in care of The British Bank of South America, Ltd., 4 Moorgate Street, London, E. C.
COM. D. E. DISMUKES, Cristobal, Canal Zone.
MR. SAMUEL E. DOANE, Nela Park, Cleveland, Ohio.
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MR. J. W. LIEB, JR., in care of Edison Company, Fifteenth Street and Irving Place, New York City, N. Y.
MR. HORACE B. SMITH, 2121 Oak Street, Baltimore, Md.
MR. ALAN WOOD, 3RD, Flat Rock, N. C.

LIBRARY NOTES.

Purchases.

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BAILEY, E. H. S., and CADY, H. P.—Laboratory Guide to the Study of Qualitative Analysis. 1914.
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NEWTON, I., BERNOULLI, D., and D'ARCY, P.—Abhandlungen ueber jene Grundsätze der Mechanik die Integrale der Differentialgleichungen liefern.
PARTINGTON, J. R.—Higher Mathematics for Chemical Students. 1912.
PICKELS, G. W., and WILEY, C. C.—Text-book on Railroad Surveying. 1914.
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John Crerar Library, Nineteenth Annual Report, 1913. Chicago, 1914. (From the Library.)
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Railroad Commission of Nevada, Sixth Annual Report. Carson City, Nev., 1914. (From the Commission.)

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Smithsonian Institution, Harriman Alaska Series, vol. 14, pts. 1 and 2, Starfishes. Washington, D. C., 1914. (From the Institution.)

U. S. Coast and Geodetic Survey, Hypsometry. Fourth General Adjustment of the Precise Level Net in the United States and the Resulting Standard Elevations. Washington, D. C., 1914. (From the Survey.)

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University of Rochester, Annual Catalogue 1913–14. Rochester, N. Y., 1914. (From the University.)

University of Tennessee, Register 1913–14. Knoxville, Tenn., 1914. (From the University.)

University of Wisconsin, Bulletin 212, March, 1914, and Circular 27th February, 1914. Madison, Wis. (From the University.)

Viaggio del Dott. Elio Modigliani in Malesia, Riascunto Generale dei Risultati Zoologici. Genova, 1909. (From Dr. Elio Modigliani.)

Waltham Water Department, 41st Annual Report. Waltham, Mass., 1914. (From the Department.)

BOOK NOTICES.

QUALITATIVE ANALYSIS by E. H. S. Bailey and H. P. Cady. Philadelphia, P. Blakiston's Son & Co. 280 pages, 13.5 x 20 cm. Price, $1.25.

It is difficult to understand why anyone thinks it necesary to add another to the endless list of manuals available to the beginner in this subject. However, the present book is a good one. Its characteristic feature is the prominence given to ionization, to the concentration-law, and to the physico-chemical explanation in general. These matters are discussed in a brief and clearly-written introduction, and are referred to at every opportunity in the course of the work. In other respects the book differs from those already in the field mainly in minor points.

ROBERT H. BRADBURY.

DIE ELEKTROLYTISCHE ALKALICHLORIDZERLEGUNG, by Dr. Jean Billiter. Published by Wilhelm Knapp, Halle, Saale. Vol. II, 182 pages, 25 x 16 cm. Price, 9.60 marks.

The first volume, which was reviewed some time ago,[1] was devoted to an exhaustive survey of the very extensive patent literature. The present volume will be much more interesting to the average chemist. It contains a description, illustrated by diagrams and half-tones, of those processes of alkali chloride electrolysis which have achieved technical importance. Among the processes which receive attention are the Griesheim-Elektron, the Hargreaves-Bird the Le Sueur, the Bell, and several others not quite so well known. The book should, of course, be in the library of every specialist in the subject. It also offers valuable information to electrochemists in general, and to teachers.

ROBERT H. BRADBURY.

KARBIDE AND SILIZIDE by Dr. Otto Hönigschmid. Published by Wilhelm Knapp, Halle, Saale. 263 pages, 25 x 16 cm. Price, 13.60 marks.

This book, like the one by Billiter just discused belongs to the series of Monographien über angewandte Elektrochemie. However, there is very little applied chemistry about it. It is simply a straightforward scientific account of the carbides and silicides, without much reference to their application. To those who have read Moissan's fascinating book, "Le Four Electrique," a great deal of the material will be familiar. However, work has been active in this field since the publication of Moissan's book, and the present volume fills a noticeable gap in chemical literature. It will be of special interest to chemists and teachers who are concerned chiefly with the inorganic side of the science.

ROBERT H. BRADBURY.

[1] J.F.I., Vol. clxxv, p. 548.

INDUSTRIAL CHEMISTRY, by H. R. Benson. Published by the Macmillan Company, New York. 431 pages, 19 x 12 cm.

This is a very brief account of chemical technology, intended especially for the use of students in engineering. Occasionally the effort to achieve briefly betrays the author into a kind of schematic treatment, which would accomplish little with the beginner. This is notably the case in the attempt to describe the fixation of nitrogen (p. 56). Chapter X, on alloys, would have been improved by paying some attention to the physico-chemical aspects of the matter. The space expended on the elaborate classification of clays, pages 239–247, might have been more advantageously employed. The various formulas given for sederite on pages 190 and 191 should be corrected.

In the main the book is accurate and up to date, and it will probably benefit the students for whom it is intended. The brief technology that will hold, in English, the unique position occupied by Ost, in German, is yet to be written.

ROBERT H. BRADBURY.

PUBLICATIONS RECEIVED.

Baltische Ausstellung in Malmö 1914. Katalog der Sonderaustellung für Fenerungstechnik. 92 pages, illustrations, quarto. Leipzig, Otto Spamer.

Aus Theorie und Praxis des Riementriebes, mit besonderer Berücksichtigung der " Riementriebe Boesner " D. R. P. Ein Handbuch zum Gebrauch beim Entwerfen von Triebriemenanlagen für Maschinen-Ingenieure, Betriebsleiter, Fabrikanten und Studierende von Fritz Adolph Boesner. 75 pages, illustrations, plates, tables, quarto. Berlin, A. Seydel, 1914.

Conférences de Radiumbiologie, faites à l'Université de Gand en 1913 par MM. Jacques Danne et J. de Nobele. Ouvrage publiè par la Société Belge de Radiologie. 214 pages, illustrations, 8vo. Bruxelles, L. Severeyns. Price, in paper, 6 francs.

Third Annual Mining Exhibition organized by the Chemical, Metallurgical and Mining Society of South Africa, Catalogue of Exhibits. 64 pages, 12mo. Johannesburg, 1914.

U. S. Bureau of Mines: Bulletin 57, Safety and Efficiency in Mine Tunneling, by David W. Brunton and John A. Davis. 271 pages, illustrations, plates. Bulletin 79, Abstracts of Current Decisions on Mines and Mining, March to December, 1913, by J. W. Thompson. 140 pages. Bulletin 82, International Conference of Mine-Experiment Stations, Pittsburgh, Pa., September 14–21, 1912. Compiled by George S. Rice. 99 pages. Technical Paper 35, Weathering of the Pittsburgh Coal Bed at the Experimental Mine near Bruceton, Pa., by Horace C. Porter and A. C. Fieldner. 35 pages, illustrations. Technical Paper 59, Fires in Lake Superior Iron Mines, by Edwin Higgins. 34 pages, illustrations. Technical Paper 62, Relative Effects of Carbon Monoxide on Small Animals, by George A. Burrell, Frank M. Seibert, and I. W. Robertson. 23 pages. Washington, Government Printing Office, 1914.

U. S. Department of Agriculture, Bureau of Biological Survey: North American Fauna, No. 36, Revision of the American Harvest Mice, by Arthur

H. Howell. 97 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1914.

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Philadelphia Department of City Transit. A program for rapid transit development with universal free transfers resulting from conferences between the Director of the Department of City Transit and the Management of the Philadelphia Rapid Transit Company. Submitted to his Honor the Mayor and the Special Committee of City Councils appointed under resolution of January 15, 1914. 16 pages, 8vo. Philadelphia, May 27, 1914.

Philadelphia Department of City Transit. Financial Aspects of the Program for Rapid Transit Development with universal free transfers. Submitted for Consideration. Statement made by Director of the Department of City Transit. 7 pages, 8vo. Philadelphia, June 2, 1914.

Benzol as a Substitute for Gasoline. ANON. (*Amer. Mach.*, xl, No. 13, 552.)—Benzol has the following advantages and disadvantages as a substitute for gasoline for automobiles. Witnesses before the Petrol Committee of the British Royal Automobile Club show that benzol appears to give, on an average, 15 per cent. more mileage and greater pulling power; its disadvantages are: (1) a difficulty in starting in cold weather, (2) a more objectionable exhaust, and (3) sooting of the valves. Benzol may be worked at higher compression and consequent greater efficiency; its tendency to freeze at comparatively moderate temperatures can be overcome by mixing it with alcohol or gasoline.

Dissipating Fog by Wireless. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—The Chemin de Fer du Nord in France is experimenting on the use of wireless waves for clearing away fog. It is well known that electric waves act upon the water particles which make up fog, so as to turn them into vapor. Following this idea, it is claimed that as much as 600 feet can be cleared up in front of the electric wires which are emitting the waves, the fog being at least partially dissipated, and this will be of great value in practice, especially for railroads and vessels at sea which will have time to avoid each other in this case.

CURRENT TOPICS.

The "Dia" Enclosed Flame-arc Lamp. P. HÖGNER. (*Elektrotechn. Zeitschr.*, xxxiv, 970.)—This article discusses the chief precautions to be observed in a successful enclosed flame-arc lamp. An important point is that the area of globe through which the main flux of light emerges should be kept hot, so that there is little deposition of the materials formed. This is attained in the "Dia" lamp by the use of two globes having a small air-space between which acts as a jacket, maintaining the temperature. The fumes are carried away and deposited in the armature above the globe, and can be conveniently cleaned at intervals. The burning hours are said to be 55 with direct current and 120 with alternating. A mean lower hemispherical candle-power of from 1800 to 4100 can be obtained with direct current, the specific consumption being from 0.20 to 0.24 watt per hefner. With alternating current the efficiency is, naturally, somewhat less. The polar curve for this lamp is given. Vertical carbons are used. Tables and diagrams are given showing how the mean, maximum, and minimum candle-power can be calculated with lamps hung at a prescribed height and distance apart.

The Daylight Effect in Radio-Telegraphy. A. E. KENNELLY. (*Radio Engin. Inst. Proc.*, i, 3, 39.)—The conclusion is reached that the changes of intensity of signals near sunrise and sunset are explained by reflecting effects which may be expected at the boundary surface or "shadow wall" between darkness (*i.e.*, air of small conductivity) and illumination (*i.e.*, air of marked conductivity). The theory and recorded observations are found to be in reasonable agreement.

Preparation of Pure Vanadium and Titanium. M. BILLY. (*Comptes Rendus*, clviii, 578.)—Titanium and vanadium were prepared in a state of purity, suitable for physicochemical determinations, by reducing the vapor of the tetrachloride (made to boil in a current of hydrogen) by contact with sodium hydride, heated to 400° C. to 420° C. The hydride was contained in porcelain boats, lined with fused salt, and could be made *in situ* by enclosing the boats in an apparatus of soft glass. The reaction was accompanied by incandescence but was not violent. Titanium was obtained as a gray crystalline powder, which was purified by treatment with alcohol, 10 per cent. hydrochloric acid, and water. Vanadium was dried in a current of carbon dioxide. The method seems capable of general application.

French Manufacture of Transparent Quartz. J. GALLOIS. (*Bull. Soc. d'Encour.*, cxxi, 205.)—Till 1911 the French were dependent on the English and German imports, but now they manufacture their own silica ware, a factory at Laigneville producing fused quartz which allows the whole mercury spectrum down to 2302 Angström units to pass through a thickness of 3 mm. of the medium, a transparency to ultra-violet rays which permits of its application to the sterilization of liquids as well as to industrial illumination and the manufacture of chemical ware. A new-mercury-vapor lamp with a quartz illuminating tube is described. In the initial position the mercury fills the illuminating tube, but when the current is started a coil attracts an armature connected by a rod with the tube, and turns the latter about 40° on its axis, whereby, on account of the shape of the tube, the mercury is divided into two portions and an arc is formed across the interval. Quartz lamps are constructed to work under tensions of 220 to 500 volts to 6600 candle-power. The most powerful will illuminate an area of 5 acres.

The Protection to Human Life Obtained by Earthing a Network. S. RUPPEL. (*Elektrotechn. Zeitschr.*, xxxiv, 1221.)—This article deals with the resistance through which connection is to be made to earth to lessen the danger from contact with any conductor. The resistance of the soil itself is very variable, according to its composition and to the temperature; in frosty weather its resistance rises enormously. Gas pipes and water pipes make a good "earth," but for various reasons they should be regarded only as auxiliary. Plates buried in water-carrying strata are good, but the cost is heavy if the necessary depth is great; moreover, there is some uncertainty as to the possibility of the water-level sinking in dry weather, in which case the resistance may rise to 100 ohms. This method may be varied by sinking iron tubes or rods. If holes are bored to the level of the water, and the pipes are then driven in, this works well; but there are various things to contend with such as the difficulty of driving the pipes to a sufficient depth without any special tackle, and the possibility of dry weather, which can be avoided, according to Creighton, by impregnating the soil with some salt solution. Another plan is to bury near the surface a considerable length of iron strip or galvanized iron wire. Thus if a length of about 50 metres of galvanized hoop iron, 25 mm. by 2 mm., is buried 35 cm. below the surface, the resistance would probably be about 3 ohms; but the moisture and the nature of the soil are important factors. The best method of protecting the poles of an overhead transmission line is then considered and curves are given showing how the voltage is distributed over the surrounding ground; and the ground might be impregnated with a solution of some salt, but it is doubtful how long this would retain its efficiency. Copper generally lasts longer than iron in the soil, though sometimes it is the reverse. For short

earthing connections, where cost is a small matter, copper wire 8mm. in diameter has been found effective. For longer connections, galvanized hoop iron, 20 mm. by 3 mm., is recommended; or a galvanized iron wire, 8 mm. in diameter, may be used, although it has a smaller surface. Under average conditions, iron has been found to last well. The "surface" method, in which a considerable length of piping or strip iron is buried at a small depth below the surface, is generally cheaper and more effective than the old plan of burying an earthing plate at a depth where it is, presumably, always moist. If the resistance is to be about 5 or 6 ohms, it is sufficient to bury about 40 metres of hoop iron, which would cost about $5; or three pipes, driven to a depth of 2.5 metres, would be equally effective. An earth-plate, about 1 metre square, would cost about twice as much to bury, unless the ground was unusually wet.

Portland Cement. A. HANENSCHILD. (*Tonind. Zeit.*, xxxviii, 477.)—Portland cement was divided into fractions of different degrees of fineness by first passing it through a sieve with 4900 meshes per square centimetre and then grading the finer portion in an air centrifuge, the material being fed through a hopper on to a distributing plate, on leaving which it was submitted to the action of a centrifugal air current, produced by a fan rotating at 2180 revolutions per minute. In this way considerable quantities of material were treated, the different fractions being collected in a series of concentric receptacles. The finest fraction contained the greater part of the sulphates present in the cement. The various fractions did not differ much in composition except in regard to the loss on ignition, which was greatest in the finest fraction and decreased progressively with the decrease of fineness. The time of setting was accelerated, the volume-weight decreased, and the volume-constancy increased with increasing fineness. The greatest strength was possessed by Portland cement grains, the dimensions of which were between 0.0363 and 0.0197 mm. The finest flour, less than 0.007 mm. in size, rapidly absorbed carbon dioxide and water, and was therefore not adapted to yield cement of the greatest strength.

Aluminum Foil. ANON. (*Brass World*, x, No. 5, 166.)—The manufacture of aluminum foil is a growing industry in southwestern Germany. The foil is used instead of tin-foil for wrapping candied fruits, etc., and has several advantages over tin. The process used is to paint sheets of pure aluminum with a solution of oil that is soluble in water, placing the sheets one upon another, or folding them, and then rolling them out to double their length. The sheets are again folded and the process is repeated until the desired thinness is obtained. The cylinders of the rolling mill are warmed with water to 45° C. (113° F.). The sheets are rolled cold and finally annealed in a vacuum retort and cooled gradually.

Casein. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—Consul W. H. Hunt, of St. Etienne, France, forwards an interesting report on some recent notable developments in the production and industrial uses of casein. Casein, the principal albuminoid matter of milk, is now obtained by electrolysis, according to the following recently invented process: In the middle of a large vat of skimmed milk, heated to 80° C., there is placed a porous vessel containing a 5 per cent. solution of sodium hydroxide; an iron cathode is plunged in the soda and a carbon anode in the milk. An electric current sets free the phosphoric acid contained in the milk, and the casein precipitates. As compared with the method of obtaining casein by the use of acids or rennet, the cost of this process is very low, the yield is greater, and the casein produced contains no foreign ingredients. Vegetable casein, now produced on a large scale from the soya bean, can be put to the same uses as animal casein. The principal use of casein is in the manufacture of galalith (milk-stone), used as a substitute for ivory, tortoise-shell, celluloid, etc. Penholders, frames, purses, phonograph discs, and a great variety of other articles are now made of galalith. It is also used as a chemical fertilizer. Several other casein products have recently been introduced.

Mercury-Vapor Lamp. BILLON-DAGUERRE. (*La Revue Elec.*, Dec. 19, 1913.)—A note on a water-cooled, mercury-vapor quartz-tube lamp with projecting mirrors. The lamp consumes 18 ampères at 70 volts, or about 1260 watts, and gives about 3000 candle-power. The principal feature of the lamp is that it produces practically "cold" light. For example, this light may fall for any length of time on celluloid, etc., without producing a heating effect on or deformation of the illuminated portion. This feature is especially advantageous for microscopy and for photography.

Preservation of Wood. A. J. WALLIS-TAYLER. (*J. Roy. Soc. Arts*, lxii, 286.)—Wood should be seasoned for at least 6 to 12 months before treatment. (1) *Kyanizing* consists in steeping timber in a 1 per cent. solution of mercury chloride for 7 to 11 days. (2) *Burnettizing* comprises preliminary steaming, followed by impregnation in a 2½ to 2 per cent. solution of zinc chloride under a pressure of 7 to 8 atmospheres. In the *zinc-tannin* or *Wellhouse* process, treatment in a partial vacuum follows the preliminary steaming, a small percentage of glue is added to the zinc chloride, and after impregnation for 2½ to 6 hours at 100 to 125 pounds pressure per square inch, the timber receives a final treatment with a 0.5 per cent. solution of tannin under the same pressure for two hours. (3) *Creosoting* usually involves steaming of the dried timber, heating under reduced pressure, and treatment with creosote oil under a pressure of 100 to 180 pounds per square inch. The amount of creosote absorbed by the timber varies from 7 to 20 pounds per

cubic foot, and the temperature of the treatment should be between 100° and 130° C. In the *Curtis-Isaacs* process, the timber and creosote are heated to above the boiling-point of the sap at ordinary pressure in a retort having vents open to the air; the vents are then closed and the creosote is forced into the wood under pressure. The *Rueping* process consists in forcing, first, compressed air at a pressure of 80 to 100 pounds per square inch into the pores of the wood, and then at a higher pressure creosote oil, without relieving the air pressure. In the *Lowry* process treatment with creosote oil at 77° to 82° C. under a pressure of 180 pounds per square inch is followed by draining and a rapid vacuum treatment. In the *zinc-creosote* or *Rutger* process an emulsion of ½ pound of "dry zinc" and 1.5 to 4 pounds of creosote oil per cubic foot of timber is used; the emulsion being continuously agitated (*e.g.*, by a centrifugal pump). The *Hasselmann* process uses a solution containing copper, aluminum, and potassium sulphates, heated 118° to 126° C. under a pressure of 35 pounds per square inch. In the *creo-resinate* process (especially suitable for wood paving blocks) air at 121° C., under a pressure of about 100 pounds per square inch, is substituted for steam; the antiseptic agent consists of 50 parts of creosote oil, 48 of resin, and 2 of formaldehyde, and impregnation is followed by a treatment with lime water at 100° C. under 150 pounds pressure. The *Guissani* process uses a mixture of anthracene and pitch heated to 140° C., in which wood is submerged until it is free from moisture and sap, after which it is successively treated with cold, heavy tar oil, and cold zinc chloride solution. In the *saccharine solution* or *Powellizing* process, suitable for the treatment of green wood, a solution consisting mainly of sugar, with a small percentage of arsenic, is used. The *Vulcanizing* or *Haskinizing* process consists in roasting wood, which has been previously dried by steaming, to a temperature high enough to coagulate its dried albumins (71° to 94° C.), and to resolve some of the fibre and sap with the production of wood creosote. In addition to the use of definite antiseptics and of a large number of metallic salts for wood preservation, mineral oils, preferably mixed with asphaltum can be used to fill up the open wood cells, thus protecting the timber from the action of heat moisture, and air. By the zinc chloride process the life of wood is more than doubled; creosoted wood lasts 25 to 50 per cent. longer than wood treated with zinc chloride, but costs three or four times as much. The amount of preservative injected into one cubic foot of various classes of timber ranges from about 3 pounds of mercury chloride in the case of hard woods to about 6 pounds for moderately hard woods and 10 pounds for soft woods, the corresponding amounts of creosote oil being 3, 10, and 20 pounds respectively. The average costs of preserving timber with zinc chloride, creosote oil, and mercury chloride are approximately 2.5 cents, 10 cents, and 16 cents per cubic foot respectively.

Earthquake Construction. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—Earthquake construction has now reached a very practical stage in the seismic districts of Italy, where all new buildings are being erected under strict supervision with regard to their ability to resist earthquake shocks. Professor Omori, the Japanese authority, has estimated that 99.8 per cent. of the deaths in the great Messina earthquake of 1908 would have been prevented if the buildings had been properly constructed.

Increasing Motor Power. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—A somewhat original method is used by the Brown-Boveri Works to increase the amount of power which a given electric motor can be called upon to furnish; for instance, where a factory uses a motor rated at 500 horsepower this new method allows of getting considerably more out of it, say 700 or 800 horsepower. This often makes it unnecessary to put in new motors for the increase of a plant, hence a great saving. The method depends upon the fact that in the induction motor the power factor often has a low value, so that the motor does not furnish nearly so much power for its size as it would were the power factor of higher value or nearly unity. For rolling mill motors, where these are subject to severe strains and overloads at times, the motor must be very much larger than the average power would demand, hence it is an advantage to use a smaller motor for the same power. This is done by a small extra device in the shape of a one-horsepower motor, coupled to a rotating commutator, and this acts to change the value of the power factor and increase the output of, say, a large 1000-horsepower motor with which it is used. The small device is connected to the circuit of the large motor.

Adhesion and Alloying of Electrolytically Deposited Metals. M. SCHLÖTTER. (*Chem. Zeit.*, xxxviii, 289.)—The degree of adhesion is satisfactorily determined by Burgess's method, in which a copper disc is soldered to the surface of the deposit, the force required to detach the latter from the underlying metal being measured by a spring balance. Several factors influence the degree of adhesion, such as nature and hardness of the deposit and of the cathode metal; generally speaking, a soft metal adheres more firmly to rough surfaces than to smooth ones. The molecular attraction between cathode and electrolyte is increased by the addition of alcohol, which improves some deposits. Several metals occlude hydrogen during electrolysis, part of which is given off subsequently as gas, which accumulates under the deposit and decreases the degree of adhesion. In some cases the deposit alloys with the cathode, and the two cannot be separated. Zinc, when copper plated first becomes yellow; the thin coating of brass is subsequently covered with the deposit of copper.

Petroleum Prospects in the Union of South Africa. E. H. C. CRAIG. (*Board of Trade* J., March 19, 1914.)—*Petroleum.*—There is little probability of any extensive oil-fields being found anywhere in the Union of South Africa. Favorable geological structure exists only in Cape Colony, and there only in a narrow strip at the southern edge of the Karroo. No petroleum prospecting has apparently been carried out in this district, but the conditions are not favorable for large productions. It is suggested that the area south of Aberdeen, near Jansenville, Saxony, and Klipplaat station should be examined. Though it is by no means certain that petroleum will be found, such a well, if successful would open up a wide area, and, if unsuccessful, would set at rest all hopes of striking oil in the Union. Certain areas in northeastern Natal, which were not inspected, may perhaps furnish favorable geological structures.

Natural Gas.—There are areas in the coal measures in the Transvaal and Natal where natural gas can be struck in fair quantity. Supplies of gas under sufficient pressure to supply distant towns are improbable, but possibly the gas may be used locally at a profit.

Oil Shales.—None of the shales examined, with the exception of that at Kikvorschfontein, are comparable with the best Scotch shales, but the laboratory tests prove that very fair quantities of shale oil can be produced. The seams are thin, as a rule, but might prove quite profitable in South Africa, on account of the great demand for and high price of oil. The Kilvorschfontein, Moorfontein, Waaihock, and Hlatimbe-Umkomaas areas are all worth consideration, especially the last area, which lies within 100 miles of Durban, and because it seems probable that shale deposits may be found near the projected railway to Himeville. Prospecting of the folded belt of the Karroo system for crude petroleum and natural gas is of less importance than the development of the shale industry. All the evidence leads to the belief that an oil-shale industry has good prospects of proving successful.

Dielectric Strength of Thin Insulating Materials. F. M. FARMER. (*Amer. Inst. Electr. Engin. Proc.*, xxxii, 2193.)—This considers the question as to the variations in results that may be expected if the dielectric strength of an insulating material is determined by different methods. It emphasizes the need for some standard method to be used for such determinations. The main point examined is the effect of the electrode area on the apparent dielectric strength, and he shows, by means of tests carried out on a larger number of dielectrics, such as varnished cambric, vulcanite, oil, air, etc., that the size of the electrodes has a marked effect on the results. The electrodes in all cases were two similar flat discs, ranging in diameter from 1/64 inch up to 15 inches. The method of making the tests is described, and the results in the various cases are shown in curves and in tables of figures. The general conclu-

sions are that the apparent dielectric strength of insulating materials in *thin* sheet form is materially higher with small than with large electrodes. This is probabaly true of solid, liquid, and gaseous dielectrics, though the variations differ widely. With paper and cloth, and with electrodes varying between the limits of size given above, the variations may amount to 50 per cent.; with oil, under the same conditions, the variation is more than 1000 per cent. The electrostatic stress is concentrated between sharp points, and failure of the dielectric soon takes place; but if the needle points are rounded off, so that the electrodes have an appreciable area, the puncture value becomes much higher than with large electrodes. This means that the testing of thin dielectric materials must be done on some specified plan, in so far as the area of the electrodes is concerned, if any comparison is to be made possible between various materials. Other variables, such as temperature, moisture of the atmosphere, and the rate of application of the testing voltage, also should be specified; but these latter points are not dealt with in the present paper.

Sicilian Sulphur Trade. ANON. (*Chem. Trade J.*, March 7, 1914.)—According to the official report of the Compulsory Sicilian Sulphur Combine for the seventh working year, from August 1, 1912, to July 31, 1913, the total production of sulphur in Sicily was 351,752 tons, against 366,457 tons in 1911–12 and 391,908 tons in 1910–11. The failure to reach the normal production of 400,000 tons is again attributed to the general conditions and to the closing in 1913 of seven mines, in addition to the 16 mines closed in 1912. The total sales during 1912–13, including sales for future delivery, amounted to 497,246 tons, against 603,255 tons in 1911–12 and 816,818 tons in 1910–11. The total exports declined from 447,638 tons in 1911–12, to 434,473 tons in 1912–13. The most striking decline in the exports is that to France, which has always imported the largest quantity, and which took 32,970 tons less than during the preceding year. This decline is believed to be due to the establishment of large refineries in that country by the Union Sulphur Company. The exports to Germany increased by 6222 tons, to Norway by 5278 tons, to Russia by 4520 tons, to Turkey by 4352 tons, and to Sweden by 3422 tons.

Fuel Oil Production. ANON. (*Amer. Mach.*, xl, No. 13, 560.)—The world's present production of fuel oils of all kinds is slightly below 55,000,000 tons, of which 47,250,000 are petroleum oils; this is about 5 per cent. of the world's present coal supply. The oil-bearing regions of the earth have been but imperfectly explored as yet, and areas known to be petroliferous still await development, though the older fields of the United States and of Southern Russia begin to show signs of exhaustion.

Plasticity and Allied Properties of Clays and Kaolins. P. ROHLAND. (*Silikat-Zeits.*, ii, 30.)—The author contends, in opposition to the views of Brown and Montgomery, that all clays lose their plasticity when heated to a temperature at which the combined water begins to be evolved, 590° to 620° C. Above about 950° C., when the combined water has been driven off, the amount of heat absorbed by clays corresponds with the contraction, which increases progressively with the temperature, well-defined contraction taking place only in the cases of substances of marked colloidal nature. The plasticity, however, is dependent not on the combined water, but on the free water, which develops the colloidal properties latent in air-dry clays. The contraction on drying of clays is also a function of their colloidal nature, and therefore of their plasticity, this contraction not occurring with crystalloids. In many cases the colloids of clays are of organic nature, but some clays which contain practically no organic matter owe their plasticity to the formation of the colloidal hydroxides of aluminum, silicon, or iron, when the clays come in contact with water. The well-known effects of caustic alkalies on the plasticity not only of clays but also of cements, trass, zeolites, and the like are due to the development of colloidal properties by hydroxyl ions, every substance of a plastic nature requiring a definite concentration of hydroxyl ions to produce the maximum proportion of colloidal constituents.

Ultra-Violet Rays as Aid to Digestion. ANON. (*Elect. World*, lxiii, 359.)—According to a cablegram to the *New York Times*, Prof. Daniel Bertholet, of Paris, claims to have reproduced artificially the processes of digestion on food substances by the action of the ultra-violet rays from a mercury-vapor lamp. The food was placed in a quartz container, and the reactions proceeded without the aid of the usual ferments.

Straw-board Pulp. B. HAAS. (*Papierfab.*, xii, 305.)—In the manufacture of the straw-board pulp, oat-straw is digested with 10 per cent., wheat-straw with 13 to 15 per cent. of lime; the capacity of the digesters ranges from 900 to 2000 kilos.; but considerable differences occur among different mills in the quality of the lime, the manner of slaking, the composition and quantity of water, and the dryness and pressure of the steam. The industry is not under general scientific control, and the quality of the product varies considerably. In many cases too much lime is employed, and the pulp becomes "greasy" and drains very slowly, clogging up wires and felts. The lime should be slaked slowly and completely and used when freshly slaked. By adjusting the chaff-cutting machine, running in the liquor at the time of charging, and steaming gently at the same time, the capacity of a digester may be increased 10 per cent. The charged digester should be rotated for a short time without

steam, then the steam admitted with the release cock open to expel the air. Then admit full pressure (4 atmospheres) of steam with the digester rotating. Digestion may be continued for two and a half to three hours.

Making Tungsten Ductile. C. TRENZEN. (*Brit. Patent* 26,800 of 1912.)—Tungsten and other metals are rendered ductile by heating the amorphous metal, which must not contain any crystalline particles or oxide, to a temperature at which it turns crystalline, viz. 1000° C. to 1200°C., and then applying strong hydraulic pressure, 12,000 kg. per square centimetre. The metal thus treated is also less liable to oxidation and may be rolled and drawn at high temperatures.

Output of Calcium Carbide. ANON. (*Amer. Mach.*, xl, No. 13, 548.)—According to a French authority, the world's output of calcium carbide in 1913 exceeded 350,000 metric tons. The autogenous welding of metals requires a large quantity, about 22,000 tons being consumed for this purpose in Germany, as compared with 28,000 tons for illuminating. The price for calcium carbide in Europe was maintained at about $55 per ton. The production and price are regulated by a syndicate, which at the end of 1913 was renewed for another term. The production of calcium cyanamide in 1913 was over 150,000 tons. The Odda works in Sweden have a plant capable of making 90,000 tons per annum. All European makers separate the nitrogen from the atmosphere by the fractional distillation of liquid air. The production of calcium nitrate in Europe is between 100,000 and 120,000 metric tons.

Mercury-Vapor Rectifier. K. NORDEN. (*Electr. World*, lxiii, 163, from *Elek. Zeit.*, Dec. 25, 1913.)—An illustrated account of the development of the large capacity mercury-vapor rectifier of the General Electric Company of this country and of the Allgemeine Elektricitäts Gesellschaft. The special feature of the latest design of the latter company is the arrangement of the anodes in such a way that no mercury can be deposited on them; which would interrupt the valve action and produce a short circuit between the electrodes. The anodes are mounted on special side arms outside the rectifier proper, and the side arms are curved so as to get the anodes entirely out of the path of the cathode flame. This construction also permits easy cooling of the anodes. Data are given on a 105-kilowatt, 300-ampère, 350-volt mercury-vapor rectifier. A test at 100-kilowatt load extending over four hours showed a practically constant efficiency of 90 per cent.

Spread of Gypsy Moth by the Wind. ANON. (*Sci. Amer.*, cx, No. 10, 195.)—Experiments conducted by the U. S. Bureau of Entomology prove that the newly-hatched caterpillars of the gypsy moth may be blown, under favorable conditions, a distance of six miles or more. Thus the wind is an important factor in the spread of this destructive pest.

Wireless Telephony from Berlin to Vienna. ANON. (*Sci. Amer.*, cx, No. 11, 227.)—Wireless telephony continues to occupy experimenters in various parts of Europe, and, although we have no very remarkable progress to report within a recent date we can mention some promising experiments which are being conducted between Germany and Austria. The Nauen wireless station, owing to its high mast, is favorable to long-distance working, and telephoning was effected from this plant to the Technical Museum at Vienna, a distance over 300 miles. Owing to special apparatus of a new design, it was possible to hear newspaper articles which were read at Nauen.

The Sixty-Cycle Rotary Converters. B. G. LAMME. (*Elect. Jour.*, x, 1124.)—The early troubles are analyzed and the effect of recent improvement shown. These are: Higher peripheral speeds and greater pole spacing, larger bars and a greater number of them in the commutator and commutating poles, allowing still greater peripheral speed. All these points tend to increased efficiency. The consequent slight disadvantages are referred to, and the adverse effect of commutating poles on "hunting" is shown. The remedy is the use of dampers on the field pole-faces. Converters run much better with turbo-generators than with slow-speed sets, the tendency to "hunt" being reduced since the angular variation of the turbo-generator is negligible. Most recent converters are self-starting, and here again commutating poles cause troublesome sparking, which can be overcome by lifting all the brushes except two. For variable voltage the synchronous booster type appears to be the only practical method for 60 cycles. The regulating-pole type requires a very crowded design of field.

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